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Soviet Rockets

As we have remarked on more than one occasion, the Russians, despite their many unjustified claims to originality, have both brains and ability. What would appear to be confirmation of this belief is contained in an interesting and well-reasoned article* by George P. Sutton, of the Aerophysics Department, North American Aviation, Inc., California, on a subject of international importance—rockets.

Mr. Sutton has collected and examined individually data and clues on Russian rocket activities and, while he admits that many of these are meagre and of questionable reliability, it is possible to obtain from all reports, reviewed as a whole, a discernible and definitely disturbing picture of Soviet rocket effort.

Reliable technical information is available on early Russian rocket research and though such work probably has little influence on Russian rocket developments to-day, it shows clearly that they had a very early start in this field, and that they displayed independent and fertile technical thought. Most notable among early Russian rocket researchers was Professor K. E. Ziolkowsky, who in 1903 proposed a liquid-propellant rocket engine in an article dealing with the possibility of space travel. He was the first to present a mathematical flight theory, and he also proposed oxygen and hydrogen as rocket propellants.

According to German intelligence, during World War II active rocket research work was carried out by Ziolkowsky and his associates in a suburb of Moscow. When the German Army approached Moscow, this rocket centre was abandoned and supposedly was transferred to Sverdlowsk in the Ural Mountains. At this research site the Germans found housing and foundations identifiable with rocket work, but discovered no rocket components or technical material. These intelligence reports are evidence of organised, systematic rocket research and development by the Russians, prior to and during World War II.

The development of rockets, as well as any other complex technical device, requires research facilities and the services of highly trained specialists. The Russians have made great progress in improving their technical and educational facilities, and it is believed that they have the background, the teachers, and the students for competent rocket research and development. Certainly, they demonstrated appreciable accomplishments in World War II, when, for instance, they put into service several types of solid-propellant rockets. In the battle of Stalingrad a new barrage rocket, a new anti-tank rocket, and new rocket launchers were used in relatively large numbers. It is significant that these rockets were used in the field before solid-propellant rockets were used extensively by the other Allies, and that the propellants used by the Russians were basically different.

Recent Russian scientific publications contain articles on the process control of ammonium nitrate production. This chemical is known to be a very cheap oxidising agent for solid propellants, but its use presupposes control of polymorphic transformations. Since ammonium nitrate has many other applications, this work does not necessarily indicate active research on this chemical for use as a solid propellant.

Several articles, which have appeared recently in various publications, are devoted to the employment of auxiliary rockets in Russian military jet-fighter aircraft. These rockets are designed to increase performance at high altitude and to augment take-off thrust. During the recent Soviet Aviation Day in Moscow, several fighter-type aircraft were observed which developed smoke trails in flight, possibly from the exhausts of auxiliary rocket engines.

Rocket assistance has been used on two specific swept-wing Soviet aircraft. The rockets apparently installed in these two aircraft were auxiliary engines and were used intermittently. A turbojet engine was the principal power plant.

There is disagreement among the references as to the details of the Russian auxiliary rocket unit. Some maintain it is a refinement of the German Walter 109-509C rocket unit; others claim it is a refinement of the German BMW 109-718 rocket engine. In either case, it is supposedly an improved and advanced version of some original German work.

From all the evidence it can be concluded that the Russians have had in operation some fighter-borne, liquid-propellant auxiliary rocket engines, which are probably a Russian development, and not simply an extension of German efforts.

One recent source indicates that the Russians are experimenting with vertical take-off and landing of fighters which are stood up on their tails and launched by rocket power. Landing is accomplished by parachute and rocket control.

The Russians are reported to have chosen nitric acid and gasoline (or kerosene) as liquid propellants for some aircraft applications. The use of gasoline or kerosene has the advantage of being essentially the same fuel for the jet engine and the rocket. They have succeeded in solving the problem of ignition, but are still faced with the difficulty of handling the very corrosive nitric acid inside an aircraft, and they undoubtedly have had to develop special techniques and procedures to cope with this problem.

Other sources indicate that research has been carried out on the combustion of oxygen with benzene and on the spontaneous ignition of aldehydes with oxygen. This interest in oxygen may be connected with their Soviet rocket work, or it may be an extension of the work done by a Russian group on the chemical kinetics of the oxidation of hydrocarbons. Men like Semenoff and Zeldovich pioneered in this field in the early nineteen-thirties. This work on oxygen, and some fundamental studies on the pumping of low-temperature liquids, indicate that the original German work with liquid oxygen may have been improved by the Russians. For long-range missiles the emphasis definitely seems to have been placed on oxygen and kerosene.

At the end of World War II, the Germans, with their development of the C-2 "Wasserfall" anti-aircraft missile and their V-2 long-range weapon experience, were far advanced in the field of guided missiles.

Although the United States has obtained many eminent German scientists, the Russians captured almost all of the rocket experimental and production facilities and probably sufficient technical personnel to operate them.

* *Automotive Industries, U.S.A.*, January 1954, page 68 *et seq.*

It is known that the Russians activated the German V-2 manufacturing facilities (Mittelwerk, near Nordhausen) and, shortly after the end of World War II, had them in operation at a reduced rate of production.

The question naturally arises, therefore, as to what they have done with all the V-2 missiles captured and produced. Some have probably been used for basic scientific explorations, such as upper-atmosphere research, aerodynamic investigations, radiation research, etc.; others may have been used to train troops in the operation of guided missiles, or to investigate improved rocket power plants and new warheads, so as to lay the foundations for future improved missiles; still others could have been stockpiled for a possible future conflict, while some could have been used for developing a V-2 of improved accuracy, higher payload, or longer range. This could imply increasing the specific thrust above the original sea-level value of 203 sec, or increasing the thrust of the rocket above the original sea-level design value of 56,000 lb. Some of the oxygen research work reported above indicates possible improvement of this type and one private communication from German sources indicates that the Russians are working on an improved V-2 missile engine with a 77,000-lb thrust.

However, no matter to which uses they may have been put, the Russians have undoubtedly profited from the experience and from having a ready-made production line fall into their hands. The V-2 has provided them with missile production knowledge and with a weapon which can deliver a warhead of 2200 lb in a range of 220 miles (or more, if they have improved the missile). A recent report claims that missiles have been launched at Kohlberg (near Stettin, Germany) and directed at the Island of Ezel, in the Baltic Sea, which is approximately 400 miles from Kohlberg. If this report is correct, the V-2 has been improved significantly. The Germans had tested a few winged versions of the V-2, which supposedly were designed for over 400-mile ranges. It is possible that the reported long-range weapon of the Russians is a winged version of the V-2 (called A-9 by the Germans), or that it is a more highly powered V-2 without wings.

The German C-2 " Wasserfall " guided anti-aircraft missile is another weapon which fell into Soviet hands. It was almost completely developed by the Germans during World War II, but lacked a satisfactory guidance system. Several completed missiles and the pilot plant for this missile are known to be in Russian possession. It is quite likely that they have worked out a guidance and control system in the last seven years, and that they are producing this C-2 missile or an advanced version.

A German source reports three other new missile developments, one of which is a small tactical missile with a range of 35 to 40 miles and a thrust of 17,600 lb. The other two developments are large missiles requiring high-thrust rocket engines. One of these is a single-stage, winged missile, with a rocket power plant which is both interesting and unusual, inasmuch as the thrust is higher than any other value previously published, and the chamber pressure is high for conventional rocket practice (880 psi, as compared with 220 psi for the V-2). The thrust at sea level of this engine is reported to be 264,000 lb, as against 56,000 lb for the V-2. The propellants used are supposedly liquid oxygen and kerosene, so that this development is not merely a straight extension of German V-2 work, as the V-2 used liquid oxygen and alcohol.

The third development is a two-stage, long-range missile, the first stage of which uses the same rocket engine as that just described. The second stage is apparently a modified V-2 type, with a thrust of 77,000 lb. The probable gross weight of the missile is between 150,000 and 175,000 lb, and its ultimate range is stated to be about 1860 miles.

With few exceptions, all of the rocket facilities built by the Germans are in the Russian zone of Germany. The famous German rocket development centre at Peenemünde is reported to be back in operation, and at least four different German missiles are reported to be in production. However, it is not very likely that the Russians are actively using Peenemünde or the Baltic Sea launching range, as these facilities are poorly located strategically and, in any case, there are several regions within the boundaries of the Soviet Union which are more suitable than the Baltic area. The regions of the Kirghis Steppe or the Gobi Desert would provide a superior launching range, particularly as the missiles would fall on the ground and would not be lost in the sea.

Any potent new rocket developments or new powerful rocket weapons probably will be closely guarded and kept secret until their use becomes imperative. For this reason it may be a long time before the full story of Soviet rocket developments will become known. Nevertheless, the clues to Soviet rocket development reviewed here indicate that the Russians have a good foundation and background in the science and engineering of rockets. They have demonstrated capabilities in this field and undoubtedly are working, or have worked, on advanced aircraft rocket power plants, on rocket-propelled missiles, and on high-thrust, large rockets for long-range missiles or satellite vehicles. They have had the good fortune to obtain German rocket-plant facilities, technicians, and production experience.

In short, the data available indicate intelligent and advanced Russian accomplishments in the rocket field. These developments should not be underestimated.

GERMAN POWER STATION WITH DOUBLE REHEAT

It is reported in the January 18, 1954 issue of *Electrical World*, U.S.A., that a 125-MW power station, designed for frequent starting and high operating efficiency at partial loads, is being built at Mannheim, Germany.

These conditions are met by limiting steam temperature to 986° F, using double reheat, maintaining a feedwater temperature of 540° F, and holding a 0·9-in. Hg vacuum at full load. The result is 38% thermal efficiency at full load and 36% at half load.

A steam temperature of 1050° F would boost full-load thermal efficiency to 39%. Frequent starting, however, makes the higher temperature undesirable, while 986° F permits the use of plain ferritic steel piping.

Turbine pressure is moderate at 2000 psi, with a relatively low steam temperature of 967° F. Feedwater temperature at 540° F is higher than that corresponding to an exhaust pressure of 850 psi, because of the residual superheat at 767° F.

As in a single-reheat installation, the high-pressure steam travels only once from the boiler to the turbine and back. Thus, there are only three main pipes, and not five, as would be necessary for double reheat in the furnace. Double reheat takes place at the high-pressure turbine exhaust heat exchangers. Pressure drop across these exchangers is only one-fifth of that in conventional furnace reheaters and piping.

With this arrangement, the condition of frequent starting is simplified. Only one superheater requires protection, instead of the three which would be involved with conventional furnace double reheat, while improved regulation and fewer safety devices are achieved as a result of the small amount of steam in the short pipe lines and their associated exchangers.

The heat exchangers used for the reheats are of an all-welded design, which has already been tested with satisfactory results in a full-size installation.

The "Dual Coolant" Cooling Method for Grinding

By G. PAHLITZSCH and J. APPLUN. (From *Werkstattstechnik und Maschinenbau*, Vol. 43, No. 11, November 1953, pp. 487-494, 11 illustrations.)

This new grinding wheel cooling method utilises two different fluids, which are supplied to the point of contact between the grinding wheel and the work separately, but simultaneously. One of the fluids is supplied externally in the normal way and the other through the wheel structure. The maximum benefit is derived from the cooling property of water and the lubricating quality of oil. Reduced wheel wear and shorter grinding times are achieved in comparison with the use of normal soluble oil emulsions.

THE use of coolants or cutting fluids generally improves the efficiency of chip-forming machining operations, in that it reduces tool wear. There is ample proof that coolants not only reduce cutting temperatures and cutting forces, but also reduce the magnitude of fluctuations. Above all, coolants improve the finish of machined surfaces.[1 to 6] Most cutting tools are affected by high temperatures because of the metallurgical properties of their materials, and lose their hardness if exposed to high temperatures over long periods. The cooling property of a cutting fluid is therefore of great importance. Efficient lubrication, however, is also an important quality in a cutting fluid, as it has a direct bearing on the degree of finish of the machined surface.

Good lubrication reduces friction between the tool and the chip, reduces tool wear, improves chip formation and chip flow, and prevents build-up on the tool face. The use of special additives may be beneficial in this respect. However, there is at present no cutting fluid which combines equal lubricating and cooling properties. The choice of cutting fluid can therefore be made only after weighing up the relative effect of high temperature and mechanical friction on tool wear in every individual case. To achieve efficient cooling and rapid heat dissipation, the cutting fluid should have a high specific heat, high evaporation temperature, and high heat conductivity; low viscosity is also an advantage, as it enables the fluid to reach the vicinity of the chip-tool interface. The increased temperature difference between the tool and cutting fluid, achieved by Pahlitzsch's method,[3 to 6] also assists in improving the cooling effect of the cutting fluid.

Water, which has the best cooling property, unfortunately has an almost negligible lubricating effect. The lubricating effect of all straight cutting oils is much superior, but their low specific heat and poor heat conductivity reduce their cooling property very considerably. Mineral oils, which are to-day used almost exclusively, have a longer useful life than vegetable or animal oils, as they resist acid and sludge formation.[7] Animal fats or oils are added in certain proportions to improve the lubricating quality of mineral oils. Extreme-pressure additives are also used to increase the load-carrying capacity. These additives are chemically active materials (sulphur, organic chloride, or phosphorus compounds) which react with the metal surface to produce monomolecular films and improve lubrication. In these cases lubrication is improved by high pressure and temperature. The local high-temperature spots caused by friction melt the material, e.g., sulphur, and in combination with the metal surface form a sulphide layer. This layer has a much lower coefficient of friction than the bare metal surface. This results in reduced tool wear and prevents the welding of small swarf particles to the tool face, i.e., build-up, and this in turn has a beneficial effect on work surface finish.[8]

THE "DUAL COOLANT" METHOD OF APPLYING GRINDING FLUID

Grinding, more than any other machining operation, requires efficient cooling as well as lubricating qualities in the cutting fluid used. The actual cutting edge used in grinding, i.e., the abrasive, is relatively unaffected by temperature (the melting point of silicon carbide is over 2000° C), and the reason for wear or blunting is mainly mechanical friction. A reduction in this friction and consequently in wear can be achieved by efficient lubrication, as provided by oil. Taskin's researches[9] have shown, however, that the temperatures at the actual point of cutting can be very high; molten particles of SiO_2 suggest local temperatures of the order of 1400° C. Even though the actual quantity of heat produced is relatively small, owing to the small chip cross-sections, the local high-temperature spots cause uneven thermal expansion and stresses, geometrical inaccuracies of the ground component, and local burns and grinding cracks. These difficulties, which arise particularly with metals having unfavourable machinability characteristics, can be prevented only by using a cutting fluid with good cooling properties, i.e., water or soluble oil emulsions. This, however, must result in more rapid grinding wheel wear and inferior finish of the ground surface, in comparison with the use of straight oil. The "dual coolant" method developed by Pahlitzsch[10] combines the advantages of water or soluble oil emulsions with those of straight oils, while eliminating their disadvantages. In this method, two different cutting fluids are brought separately to the cutting point. Water or a soluble oil emulsion in the usual quantity is supplied externally and tangentially to the wheel, whilst a very small quantity of oil is brought to the wheel bore and penetrates to the periphery, i.e., to the cutting point, through the porous grinding wheel structure. In addition to the combined cooling and lubricating effect. the method offers additional advantages. The grinding wheel pores are kept free from swarf by the centrifugal pressure of the oil, and the formation of oil mist, normally associated with straight oil, is prevented.

The idea of supplying a fluid to the cutting point through the grinding wheel structure was first mentioned in a patent before the year 1900, but the first experimental results were reported only in 1948 from the U.S.A.[11] According to these results, plain internal cooling with 1 to 4 drops of fluid (approximately 2-8 grams/min), without any auxiliary external cooling, reduces the temperature at the point of contact by several hundred degrees. This report, unfortunately, does not describe the method of temperature measurement; in view of this, and of other results communicated to the authors privately from the U.S.A., none of which indicates an improvement over plain internal cooling, some doubt must be expressed. This is supported by the fact that, with plain internal cooling, only that proportion of the fluid which strikes the work as it is thrown off the wheel, is effective. The volume of effective coolant is proportional to the engaged arc b of the grinding wheel, and is of the order of 10-15% of the total volume of coolant. The arc b can be calculated from the following equation:

$$b = \frac{D}{2} \cos^{-1}\left(\frac{D-d}{D+d}\right)\frac{100}{\pi D}\ [\%]$$

It has been shown in tests carried out by the authors that, where equal volumes of coolant were used, internal cooling resulted in higher work temperatures than normal external cooling.

Results of other research in the U.S.A. were pub-

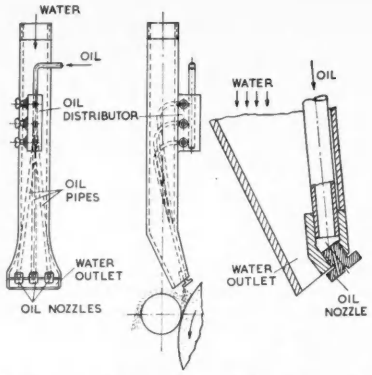

Fig. 1. **Dual method of supplying coolant when grinding, according to U.S. Patent 621,391 (Norton).**

lished in the meantime.[13] Relatively complicated equipment was used to supply two different fluids externally to the point of contact between wheel and work; the oil was conducted through a number of thin tubes to fine nozzles and sprayed the wheel in a number of divergent and overlapping jets (Fig. 1). The thin oil tubes were situated inside the main coolant supply pipe, and the water or soluble oil emulsion had to provide the cooling and to prevent the formation of oil mist during spraying and grinding. Whilst it is claimed that this method was successful, it requires individual circulation systems, continuous separation of the two fluids, and artificial cooling.

"DUAL COOLANT" METHOD GRINDING TESTS

The new method was thoroughly tested,[14] using grinding wheel wear and work surface finish as criteria. The method was also compared with conventional external cooling and plain internal cooling. The effect of varying volumes of internally supplied oil was also determined. Cylindrical testpieces used were 20 in. in length and 3¾ in. in diameter, made of an alloyed tool steel, and heat treated to 40 Rockwell C. They were ground on a cylindrical grinding machine, using a normally porous wheel, type 80 I/J8/5, and an extra-porous wheel, type 80 G/H.

Other details are as follows:—

Grinding wheel:
- Diameter .. .. D ≈ 425 mm
- Width .. .. b = 40 mm
- Peripheral speed .. v_s = 32 m/sec

Speed ratio .. .. v_s/v_w = 86
Work diameter .. d = 95-78 mm
In-feed per pass .. a = 5μ (1μ = 0·001 mm)
Grinding volume (theoretical) V_z = 100 cm³
Total in-feed .. .. Σa = 680-840μ
No. of sparking-out passes p = 2
Work feed rate .. s = 20 mm/rev
Table feed rate .. v_T = 1·5-1·8 m/min
Cutting fluids:
- Grinding oil M20 (Shell)
- Soluble oil emulsion 8424 (Shell)

The tests have shown the dual method to be considerably superior to any other existing method with respect to both wheel wear and work finish. Moreover, the amount of oil required to achieve these results is very small. The internally supplied oil reaches the actual point of cutting and covers the abrasive with a protective anti-friction film. Swarf and other particles are prevented from entering the wheel structure by the escaping fluid; the wheel surface is therefore kept cleaner and retains its cutting efficiency. This results in better work finish and assists in the self-dressing action of the wheel periphery.

The bar charts in Figs. 2 and 3 summarise the test

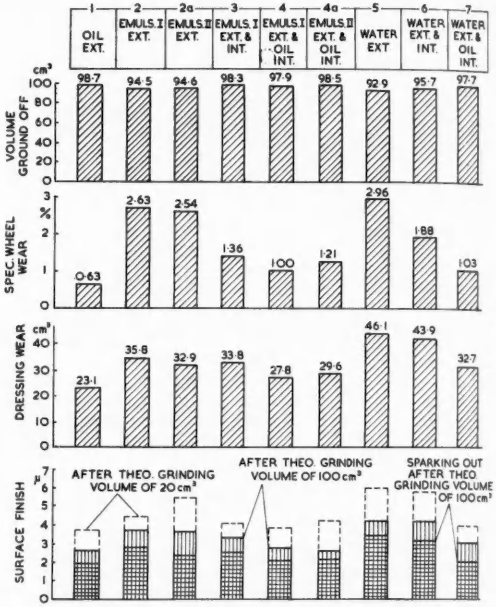
1 OIL EXT.
2 EMULS. I EXT.
2a EMULS. II EXT.
3 EMULS. I EXT. & INT.
4 EMULS. I EXT. & OIL INT.
4a EMULS. II EXT. & OIL INT.
5 WATER EXT.
6 WATER EXT. & INT.
7 WATER EXT. & OIL INT.
VOLUME GROUND OFF cm³
98·7 94·5 94·6 98·3 97·9 98·5 92·9 95·7 97·7
SPEC. WHEEL WEAR %
0·63 2·63 2·54 1·36 1·00 1·21 2·96 1·88 1·03
DRESSING WEAR cm³
23·1 35·8 32·9 33·8 27·8 29·6 46·1 43·9 32·7
SURFACE FINISH μ
AFTER THEO. GRINDING VOLUME OF 20 cm³
AFTER THEO. GRINDING VOLUME OF 100 cm³
SPARKING OUT AFTER THEO. GRINDING VOLUME OF 100 cm³

Fig. 2. **Grinding test results, with various methods of cooling, after reaching a theoretical grinding volume of 100 cm³.** Grinding wheel: Type 80 I/J8/5.

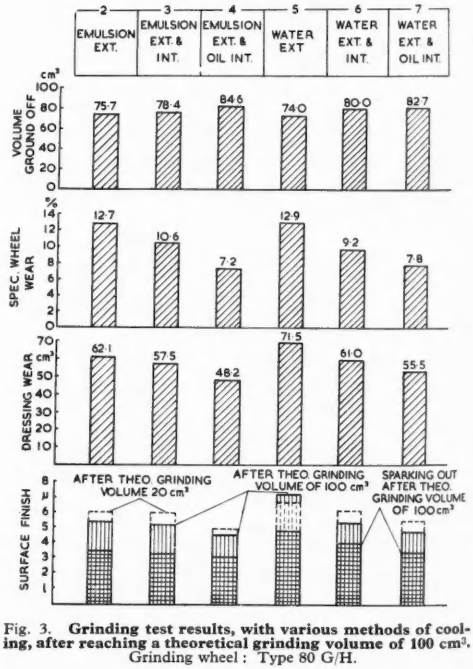
2 EMULSION EXT.
3 EMULSION EXT. & INT.
4 EMULSION EXT. & OIL INT.
5 WATER EXT
6 WATER EXT. & INT.
7 WATER EXT. & OIL INT.
VOLUME GROUND OFF cm³
75·7 78·4 84·6 74·0 80·0 82·7
SPEC. WHEEL WEAR %
12·7 10·6 7·2 12·9 9·2 7·8
DRESSING WEAR cm³
62·1 57·5 48·2 71·5 61·0 55·5
SURFACE FINISH μ
AFTER THEO. GRINDING VOLUME 20 cm³
AFTER THEO. GRINDING VOLUME OF 100 cm³
SPARKING OUT AFTER THEO. GRINDING VOLUME OF 100 cm³

Fig. 3. **Grinding test results, with various methods of cooling, after reaching a theoretical grinding volume of 100 cm³.** Grinding wheel: Type 80 G/H.

results[4] for both wheels, with a theoretical grinding volume of 100 cm³.* The heights of the bars represent the actual volume ground off, specific wheel wear, wear due to dressing, and surface finish of the test piece.

EFFECT OF COOLANT ON THE GRINDING PROCESS

The results for wheel 80 I/J8/5 in Fig. 2 show the order of merit of various coolants with normal external application, and this corresponds with results of earlier researches,[9, 12, 15] i.e., oil (No. 1), emulsion (No. 2) and water† (No. 5). Using oil, the specific wheel wear is only about 25% and 20% of that obtained with emulsion and water respectively. Oil is also much superior with respect to the surface finish of the component, the finish when using water being particularly rough. The reasons for the superior results lie mainly in the more favourable friction conditions due to superior lubrication; this can be further improved by the inclusion of fatty oils and extreme-pressure additives.

The disadvantages of using oil for normal external cooling were, however, also quite clearly shown. The poor cooling property of oil became quite marked, owing to the bad machinability of the test material. The testpiece heated up considerably and, owing to the high local temperatures, it also expanded unevenly and became distorted. These observations agree with those of Vits[15], who states that oil coolant should be used only for very light grinding, where heating-up may be expected to be relatively small. The strong tendency for oil-mist formation is an additional shortcoming. The impact of the oil on the grinding wheel and workpiece, and the subsequent acceleration, cause atomisation of the oil, which has a very low surface tension. The very fine mist resulting settles in the vicinity of the machine, soon forming an oily film. This is not only unpleasant for the operator, but also causes considerable wastage of oil. The use of an exhaust system partially removes the unpleasant effect, but does not prevent oil wastage.

EFFECT OF THE "DUAL COOLANT" METHOD ON THE GRINDING PROCESS

The results in Fig. 2 also show the advantages of the "dual" method, irrespective of the type of coolant used. Even the external and internal combination of similar fluids, e.g., emulsion (No. 3) or water (No. 6) gives considerable improvements in wheel wear and work finish, as compared with plain external emulsion or water cooling (No. 2 and No. 5). This indicates that external cooling, even if large quantities of coolant are used, does not enable the fluid to reach the actual point of contact between the wheel and the work in adequate measure. With the internal or "dual coolant" method of cooling, this actually does take place; the abrasive particles are coated with a film of coolant and the coolant is continuously exuding from the peripheral pores of the wheel. The results also show that this film is formed even when very small quantities of fluid are used. It must, however, be mentioned that a relatively large volume of coolant (100 gr/min) was required to improve grinding results when emulsion or water was used internally. This would make the application of the dual method rather difficult in practice, as the fluid supplied internally must be very carefully filtered. The best results with the dual method were achieved when oil was used internally (No. 4 and No. 7). Despite the small volume of approximately 10 gr/min, the results were comparable with those obtained with normal external oil cooling (No. 1). Specific wheel wear, when using oil internally and emulsion and water externally, was 62% and 65% less than that obtained with plain external cooling with emulsion or water. This does not quite compare with results of plain external cooling with oil, which show 76% less wear.

Similar results were obtained insofar as surface finish is concerned. Surface finish, using emulsion externally, is 50% worse than that obtained with externally applied oil. The dual method, using emulsion/oil and water/oil, shows a considerable improvement over plain external emulsion cooling, but these results are still 15% inferior to those obtained with plain external cooling, using oil.

In addition to these advantages, the reduction in wear due to wheel dressing is also of importance. When using the dual method, particularly with internally applied oil, the wheel structure remains cleaner. Wheel dressing, to restore the wheel surface, can therefore be reduced, as compared with the wheel dressing required when using corresponding external cooling. The high wetting power of the oil and its chemical reaction and mutual adsorption with metal cause the metal chips to be enveloped in oil. They are then carried away with the oil and cannot block the pores of the wheel structure. The distortion of chips is also decreased by reduced friction, as pointed out by Opitz[16]; they remain straighter and cannot easily enter the wheel pores.

The dual method also gave similarly satisfactory results in tests with the extra-porous wheel, type 80 G/H, and these are summarised in Fig. 3. The values of wheel wear and surface finish were considerably higher with this wheel than comparable values obtained with wheel 80 I/J8/5. This is due to the different structure of this highly porous wheel and to its slightly lower hardness. The advantages of the dual method, however, were maintained with respect to both surface finish and normal and wheel dressing wear. The tests also clearly show the poor results obtained with water; for example, the surface finish shows some deterioration with increasing grinding volume. The effect of sparking-

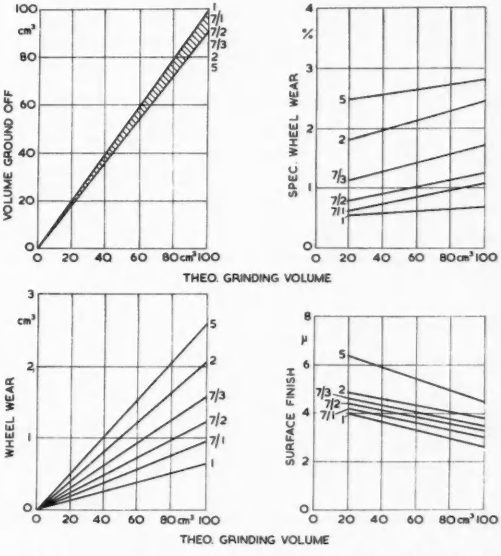

Fig. 4. **Volume ground off, wheel wear, and surface finish, using various cooling methods and coolant quantities, with type 80 I/J8/5 wheel.**

(1) Oil, external; (2) emulsion, external; (3) water, internal. 7/1 Water external and 10 gr/min of oil, internal; 7/2 water external and 2 gr/min of oil, internal; 7/3 water external and 1 gr/min of oil, internal,

* Grinding volume is calculated from the total in-feed (Σa) and the testpiece diameter and length. Grinding volume should always be used in such tests, instead of pure in-feed, as only then are testpiece dimensions taken into account.

† Water is always understood to contain a 0·2% solution of K_2CrO_4.

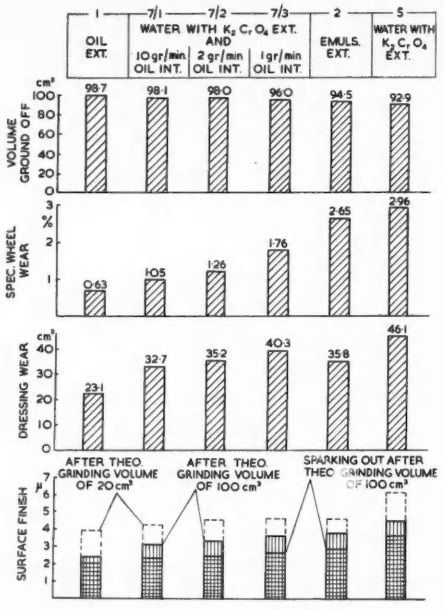

Fig. 5. **Grinding test results, with the dual method and with various coolant quantities, after reaching a theoretical volume of 100 cm³.**
Grinding wheel : Type 80 I/J8/5.

out on surface finish, when using the highly porous wheel, is about twice that obtained with the normal wheel. This can be explained by the smaller number of abrasive particles and the higher specific loading of each particle. This causes higher wheel wear, inferior surface finish, and improved effect of sparking-out, despite the larger volume of bond material.

EFFECT OF QUANTITY OF INTERNALLY SUPPLIED OIL ON THE GRINDING PROCESS

The object of the following tests was the determination of the minimum quantity of oil which could be used, without reducing the beneficial effect of the dual method. In the tests previously described, a constant oil quantity of 10 gr/min (No. 7/1 in Fig. 4) was used. The quantity was reduced to 2 gr/min (No. 7/2) and 1 gr/min (No. 7/3) in these additional tests. Fig. 4 compares the ground-off volume, wheel wear, and surface finish resulting from tests using the three varying quantities of oil and three normal cooling methods, plotted against a range of theoretical grinding volumes. The results are summarised in bar chart form in Fig. 5, and indicate that the reduction of oil quantity to 2 gr/min has no appreciable effect on wheel wear and surface finish. A further reduction, however, does to a certain extent reduce the superiority of the dual method over normal external cooling.

The influence of oil quantity on volume of material ground-off, wheel wear, and surface finish is shown in Fig. 6, in which these criteria are plotted against the various oil quantities used in the tests. The results are seriously effected only by reductions of oil quantities below 2-3 gr/min. Results of all the tests are summarised in bar chart form in Fig. 7, where the performance of all the various coolants is related to that of a commonly used soluble oil emulsion.

SPECIAL CHARACTERISTICS OF THE "DUAL COOLANT" METHOD

(1) Chatter marks appeared on the testpiece under certain conditions after approximately half the total test period, when using pure external cooling, and particularly when using water. Such chatter marks occurred only in isolated cases when using the dual method and then only just before the end of the test period, i.e., after a much larger volume of material had been ground off.

(2) The results have shown that the combination of oil and emulsion gave the best results. Additional advantages of this combination over the combination of oil and water were also indicated. The oil expelled from the periphery of the wheel rapidly covers the workpiece with a thin oil film. This is favourable to the actual grinding process in that even the smallest metal particles are covered with oil before they come into contact with the wheel. This oil film, however, is harmful when water is used externally in the dual method, as full advantage cannot be gained from the ideal cooling qualities of water. The poor wetting property of water deteriorates even further on the oil film, and the water is quickly thrown off the workpiece, without appreciably reducing its temperature. This disadvantage was not noticeable when the combination of oil and emulsion was used. On the contrary, the emulsion clung to the oily surface and was brought to the point of contact in adequate quantity.

(3) The recovery and re-use of the internally supplied oil become a point of some economic importance, despite the very small consumption. Observations during the tests showed that recovery can be achieved quite simply. The oil and the externally applied coolant drain into the coolant tank and separate quite rapidly, an oil layer being formed on top of the heavier, water-base liquid. The oil can then be drained off and mechanically filtered before re-use.

(4) Previous tests have shown[13] that, once the wheel structure has been filled with oil, it remains saturated for some time after the oil supply has been cut off. This is advantageous in cases of temporary failure of the oil supply and ensures that at least a reduced supply will be available until full supply is restored.

(5) A type 80 I/J8/5 wheel, correctly statically balanced when dry, was saturated with oil and its unbalance measured during a 48-hour running period at 6-hour intervals. The maximum unbalance was 6 cm-gr. After the wheel structure had been flushed with trichlorethylene and dried, perfect balance was restored.

(6) The comparative tests summarised in Fig. 7 have shown the following savings when using the dual

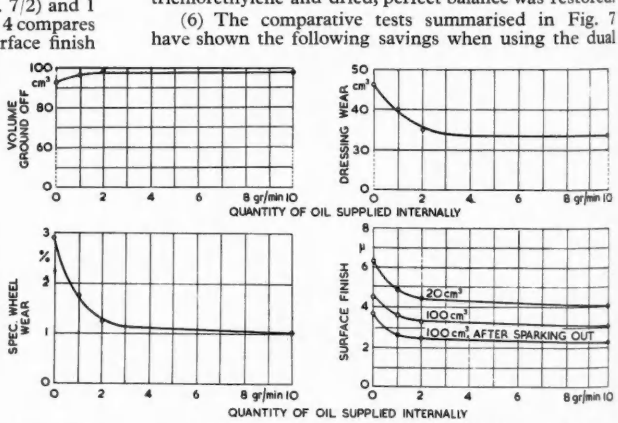

Fig. 6. **Volume ground off, wheel wear, and surface finish, in relation to the quantity of oil supplied in the dual method (water external, oil internal), after reaching a theoretical grinding volume of 100 cm³, with grinding wheel type 80 I/J8/5.**

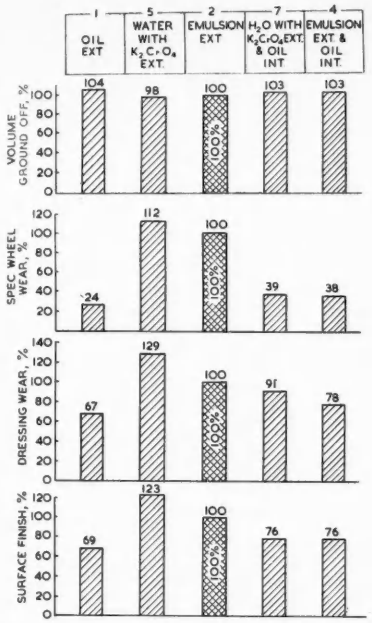

Fig. 7. **Grinding test results, using various cooling methods, after reaching a theoretical grinding volume of 100 cm³, by comparison with soluble oil emulsion, external (= 100%), with type 80 I/J8/5 wheel.**

method, as compared with purely external cooling with an emulsion :—

(a) Saving of grinding wheel material,

normal wear	62%
loss due to dressing ..	22%

For an overall wheel wear of 29 cm³ and 38·5 cm³ with the dual method and external emulsion cooling respectively, savings in grinding wheel costs amount to 25%.

(b) The frequency and extent of wheel dressing required to maintain a clean and sharp wheel periphery is reduced when using the dual method. The saving in time, and hence in labour and machine costs, is 22%.

(c) The 24% improvement in surface finish also has an important bearing on grinding costs. To achieve the same final surface finish, the grinding speed or feed can be increased. This shortens the total grinding time, resulting in a saving of some 35%, related to the total grinding time (see Cost Analysis, below).

COST ANALYSIS

The following cost analysis shows the actual financial savings achieved when the dual method is used :—

Test data:

Grinding wheel diameter	D	= 450 mm
Workpiece diameter ..	d	= 100 mm
In-feed per pass ..	a	= 0·005 mm
Table feed rate ..	v_T	= 1 m/min

Under the above conditions, the volume of material ground off per second is 25 mm³ ; in a seven-hour day, allowing for wheel dressing, the volume becomes 500 cm³. According to Reiber[17], the wheel should be dressed after 25 cm³, i.e., about 20 times per day. Each dressing operation should consist of four double passes with an in-feed of 0·015 mm per pass, and two double sparking-out passes. The volume of wheel material removed in each dressing is therefore $V_A \approx 8$ cm³, i.e., $20 \times 8 = 160$ cm³ per day. The time required for dressing, using a table feed of $v_T = 0{\cdot}25$ m/min, is 3·6 min including allowances, and 72 min per day.

(a) Assuming the cost of the grinding wheel to be 0·5d* per cm³, a 22% saving of wheel material, due to dressing, equivalent to 35 cm³ per day, and a 62% saving of wheel material, due to normal wheel wear, equivalent to 15 cm³ per day, the actual savings are :

Dressing : $35 \times 0{\cdot}5 \approx 17{\cdot}5$d per day
Grinding : $15 \times 0{\cdot}5 \approx 7{\cdot}5$d per day

(b) The savings in labour and machine costs for dressing, at a combined rate of 200d per hour, are $72 \times 22/100 \times 200/60 \approx 53$d per day.

(c) An overall reduction in grinding time, for a given final surface finish, is also possible. Conditions which should give a work finish of 3 μ with the dual method, would result in a finish of only 4 μ with normal emulsion cooling. According to Saljé,[18], therefore, it should be possible to increase the table feed from 1 m/min to 1·6 m/min. At this feed rate the volume ground off per second is 40 mm³. The time for a total volume of 625 cm³ is therefore approximately 4·5 hours, representing a saving of 2·5 hours per day. Assuming a cost rate for labour and machine of 200d per hour, the saving amounts to 500d per day.

The overall savings per day are therefore 25d + 53d + 500d = 578d = £2 : 8 : 2.

The following additional costs, however, must also be considered :—

(i) Additional oil consumption is 1 litre per day. The equivalent cost is about 40d per day. This additional cost can be avoided, if the oil is reclaimed and re-used.

(ii) The capital cost of two special grinding wheel flanges and of the supply installation is about £125. The depreciation rate for a year would be £25, or equivalent to 20d per day.

The additional costs per day are thus 40d + 20d = 60d = 5/-. Thus, the overall saving per day, allowing for additional costs, is £2 : 3 : 2, or £647 : 10 : 0 per year of 300 days.

* Costs in the original article are given in DM. They have been been converted on the basis of £1 = 12 DM. Editor, E. D.

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Contactless Frequency Relays

By F. A. Katkov. (From *Elektrichestvo*, No. 10, October 1953, pp. 40-42, 5 illustrations.)

Existing frequency relays are inclined to be unreliable, mainly because their actuating force must overcome not only a set spring resistance but also the friction of the moving contact mechanism. This makes it difficult to ensure stable response characteristics of the relay. Another source of instability in the resonant circuits used in electromagnetic and induction-type frequency relays is the paper condenser, whose capacity greatly depends on ambient temperature. Moreover, the inductance of the choke in the resonant circuit also varies with changes in mains voltage and with ambient temperature. This causes the operating frequency of the relay to be substantially dependent on ambient temperature, while ageing of the condensers continuously alters the relay setting.

Frequency relays, with vibrating contacts and without condensers, were introduced to remedy these defects. However, as is inevitable in the circumstances, the presence of periodically operating contacts prevents the achievement of maximum operational precision and reliability.

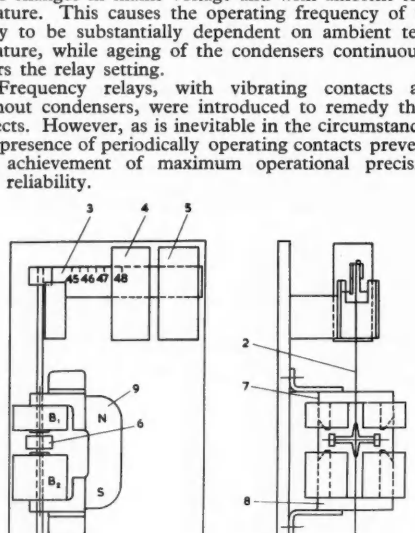

Fig. 1. **Arrangement of sensitive element of contactless frequency relay.**

A new contactless frequency relay has been developed by the author. Its sensitive element is a suspended vibrating system, excited by a polarised vibrator coil system, as shown in Fig. 1. A steel tape (2) is attached at its lower end to a bracket (1) and at its upper end to the short arm of a lever (3). This lever rocks about the knife edge of a steel prism. Weights (4) and (5) can be moved along the long arm of the lever. The armature (6), attached to the centre of the steel tape, can move in the gap between two electromagnets (7) and (8), whose poles are polarised by the permanent magnet (9). The windings B_1 of the upper electromagnet are in the exciting (input) circuit, and the windings B_2 of the lower electromagnet are in the power (output) circuit.

When an a.c. voltage is applied to the exciting windings, the armature vibrates at the frequency of the voltage. This vibration modulates the constant magnetic flux in the cores of the output windings, in which is thus induced an alternating e.m.f. E_n whose phase and magnitude depend on the frequency of the applied voltage and the adjustment of the vibrating system. The two electromagnets are also connected by a transformer linkage, as a result of which a further e.m.f. E_m is induced in their windings. This latter e.m.f. is not related to the vibrations of the armature. The resultant e.m.f. is :

$$E = \sqrt{E_m^2 + E_n^2 + 2E_nE_m \cos \varphi} \quad .. \quad (1)$$

The induced e.m.f. E_m is proportional to the amplitude of armature vibrations in the vibrating system and coincides with their phase. It can be shown that

$$E_n = \frac{E_0}{\sqrt{\frac{1-k^2}{kd} + 1}} \quad .. \quad .. \quad (2)$$

and

$$\varphi = -\tan^{-1}\frac{kd}{1-k^2} \quad .. \quad .. \quad (3)$$

where $k = \omega/\omega_0 = f/f_0$; f and f_0 are the frequencies of the forced and the free oscillations of the system, respectively ; d is the damping coefficient of the vibrating system ; and E_0 is the e.m.f. induced in the output windings at $k = 1$.

Introducing the notation $\rho = E_m/E_0$ .. (4)

and substituting the expressions (2), (3), and (4) in (1), the following final expression for the resultant e.m.f. in the output winding of the relay is obtained :—

$$E = E_0\sqrt{\rho^2 + \frac{1}{\Psi^2+1} + \frac{2\rho}{\Psi^2+1}\cos\tan^{-1}(1/\Psi)} \quad (5)$$

where $\varphi = (1-k^2)/kd$

Fig. 2 shows a graphical representation of eq. (5), where $d = 0{\cdot}02$, and it will be seen that the relay so described has a characteristic typical of contactless relays. With an increase in ρ, the steepness of the left part of the characteristic curve is reduced and that of the right or working part is increased.

In practice it is advisable to choose ρ between 0·3 and 0·4 as, beyond this value, the steepness no longer increases, but the output voltage, at mains frequencies above the frequency of release of the relay, rises beyond the input voltage—an undesirable feature. An experimentally determined characteristic curve, which agrees

(*Concluded on page* 100)

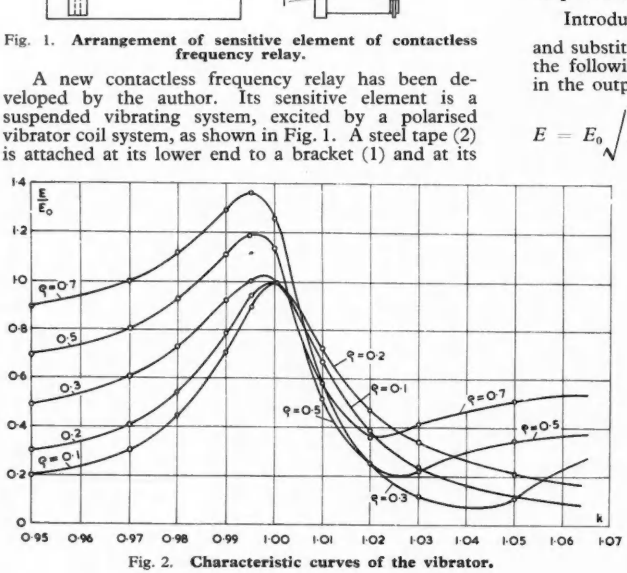

Fig. 2. **Characteristic curves of the vibrator.**

Slag Deposition and Corrosion in Gas-Turbine Plants

By J. BIERT and R. SCHEIDEGGER. (From *Schweizer Archiv*, Vol. 19, No. 12, December 1953, pp. 359-366, 3 illustrations.)

The materials used in gas turbines, besides having certain physical and mechanical properties obtained by special technological processes, must also be capable of resisting attack by corrosive substances contained in the burnt gases.

This article describes the difficulties occurring in the high-temperature operation of gas-turbine plants and considers possible solutions to the problem of slag corrosion due to ashes of fuel oils.

In stationary gas turbines, it is an economical advantage to make use of cheap fuel oils, which consist of residues of petroleum distillation or residues mixed with distillates. These fuel oils contain mineral, ash-forming constituents, which normally include some of the following substances : Na_2O, CaO, NiO, V_2O_5, and SO_3, as well as Fe_2O_3, Al_2O_3, SiO_2, K_2O, and small quantities of MgO, MnO, CuO, etc. These substances are either already present in the crude oil, and are obtained in concentrated form in the residual oil in the course of processing, or occur as external impurities, which come into the fuel through improper handling during storage or transport. Mineral constituents of fuel oils can be extremely detrimental to gas turbines operating at high temperatures, since they cause a reduction of the swallowing capacity of the turbine, and corrosive fouling of components.

SLAG DEPOSITION IN TURBINE PASSAGES

The mineral constituents leave the flame in the form of liquids (molten ash, the organic substances being completely burnt) or solids (the core of the incompletely burnt oil droplet is surrounded by a hard coke-like layer) and are carried away by the flue gases. If the liquid particles impinge on obstructions, e.g., turbine blades, in the path of the flow, they will adhere to these more or less firmly, according to their viscosity and surface tension and the condition of the point of impact. If the latter is at a temperature above the melting point of ash, or if the liquid slag has a low surface tension (i.e., high wetting capacity), it will spread out as a thin liquid film on the surface of the component. On the other hand, if the temperature is below the melting point of ash, the liquid slag droplets will solidify after impact and adhere more or less firmly to the solid surface. As regards the solid ash particles, it can be assumed that some of these are retained by the sticky liquid surface films, while the remainder reach the stack with the gases. Depending on their hardness, there is also a risk of erosion of the surfaces on which the entrained particles impinge.

The deposits begin to build up approximately as outlined above. The physical and chemical conditions associated with deposition are extremely complicated and difficult to determine experimentally. The chemical composition and physical state of the ash, the temperature of the point at which deposition occurs, and its surface quality are among the important factors. At present, far too little knowledge is available of the relations between these factors to enable definite predictions to be made solely on the basis of fuel-oil analyses. Among the ash-forming components, some compounds of sodium and vanadium (sodium vanadyl vanadates and sodium metavanadates) have the lowest melting points, whereas those of sodium sulphate and vanadium pentoxide are very much higher (884° and 650-690° C, respectively). It is also probable that eutectoids may occur, with much lower melting points than the compounds previously mentioned.

Up to a few years ago, it was believed that the slag deposits of heating oils in Velox boilers and gas turbines could be removed by water, if the ash analysis showed a solubility of about 50%. Experience in recent years has shown, however, that this assumption is correct only under certain conditions, and is absolutely valid if the ash consists mainly of sulphates of the alkaline metals and of magnesium. The conditions are complicated if calcium and vanadium compounds are also present. Usually, laboratory tests of ash solubility are arranged so as to allow calcium sulphate to dissolve. With vanadium compounds, the problem is more difficult ; vanadium pentoxide is in most cases insoluble, but by peptisation it can enter the solution in a colloidal state ; reactions with other substances present are also possible, resulting in the formation of vanadyl sulphates and metal vanadates of varying solubility. Furthermore, the structure of the deposits should be considered. It is convenient in this connection to distinguish three cases :—

(1) *Loose, porous deposits:* The water can penetrate everywhere and thus dissolves the easily soluble constituents fairly rapidly. The remaining portions no longer have their combined strength and can be washed away satisfactorily.

(2) *Solid, compact deposits:* Where these still have some absorption capacity, the wetted area is smaller than in case (1), and solubility is also more difficult, so that removal by water is much slower.

(3) *Fused-ash deposits:* Where these have an impervious glass-like surface, removal is more difficult, even for deposits with a fairly high solubility in water.

The previous observations concerning Velox boilers and gas-turbine plants can be commented upon as follows :—If the deposits can be dissolved or washed away, cleaning is fairly simple and requires only short interruptions in service. Otherwise, mechanical cleaning is necessary, though this is a complicated operation which should be avoided as far as possible. Unfortunately, the position is such that no absolutely definite conclusions can be derived from the ash analysis regarding the properties of the corresponding deposits.

Besides impeding the gas flow and reducing the heat transmission (in air preheaters), with an attendant decrease in efficiency, slag can also attack the metals on which it is deposited. As it is hardly probable that the petroleum industry will in the near future put on the market cheap ash-free fuel oils for stationary gas turbines, the presence of mineral substances in boiler fuels constitutes a definite problem. Valuable experience has been gained with gas turbines operating at temperatures between 500 and 650° C. Further knowledge can be obtained only with full co-operation between designers, works engineers, and chemical departments. Since knowledge of the mechanism of deposition is incomplete, it is essential to collect and evaluate as much statistical information as possible on, among other things, ash analysis of the fuel used ; composition of slag at various positions in the plant ; gas and wall temperatures, as well as gas-flow conditions at these locations ; and combustion conditions (atomisation, pressure, etc.). A basic requirement, however, is that the plant should operate on the same type of fuel for at least three months, to obtain representative data.

For preventing or reducing slag deposition, there are various possibilities which require testing and individual investigation, as follows :—

Conversion of vanadium into compounds with a high melting point ; volatilisation of vanadium ; reduction of operating temperature below the melting point of the ash ; use of materials of suitable surface quality ; and use of surface-protecting layers.

CORROSION OF METALLIC MATERIALS

Before discussing the possible effects of corrosion in gas-turbine plants, it is necessary to consider the

types of corrosive agents. Normally, the combustion gases contain the following corrosive substances :—

(a) *Gases:* Oxygen, carbon dioxide, sulphur dioxide and a proportion of sulphur trioxide, and vanadium pentoxide from the combustion of vanadium-containing boiler fuels at high temperatures.

(b) *Liquids:* Molten minerals, more or less in accordance with the ash composition.

(c) *Solids:* Cokes with ash, and solid slag.

The solid deposits can cause erosion only, not corrosion. With regard to gases, in gas-turbine plants the gas atmosphere always has an oxidising action (large amount of excess air), so that it is necessary to investigate the effects of oxygen and oxygen-carrying components on steel at high temperatures. It is known that all metallic materials have on their surface a thin invisible film of oxide, which separates the base metal from the oxygen in the reaction. This film is a most important factor in the resistance of the metal or alloy to further chemical attack on its structure.

The study of the surface structure requires consideration of the following points :—Study of atom geometry and composition of the outermost lattice plane which is in contact with the gas atmosphere ; investigation (chemical or electro-chemical) of the oxides removed from the base metal ; and investigation of the secondary structure of the film.

It is very difficult to determine the chemical nature of the oxides, owing to the small amount of material available in most cases for chemical analysis. The determination of the crystal structure by means of X-rays is also difficult, as most of the oxides in surface films have very similar crystal lattices.

The probability that a specific oxide will be formed depends on the similarity of the crystal lattice (structure and crystal dimensions) to that of the metal on which it is situated. Thus, Goldschmidt,[1] for instance, was able to show that cubic crystals of FeO and Fe_3O_4 (spinel type) easily develop from the α-Fe-lattice, whereas the rhombohedral lattice of α-Fe_2O_3 differs considerably from the cubic surface-centred α-Fe. It is therefore understandable that FeO and Fe_3O_4 are in contact with metallic Fe, whereas Fe_2O_3 appears further outwards on the oxide surface.

When various metals are present as, for instance, in alloys, the oxidation sequence depends not only on structural factors but also on the thermodynamic stability of the individual metal oxides. Thus, for aluminium, vanadium, chromium, titanium, manganese, molybdenum, tungsten, iron, nickel, cobalt, and copper, occurring in alloy steels, the oxidation sequence is from left to right, i.e., the elements on the left of iron oxidise earlier, while those on the right oxidise later than the base metal. To protect any base-metal B against oxidation, an alloying metal A should oxidise before B ; otherwise, the oxidation of the base metal develops approximately to the same extent as when A is not present, and A remains as a metal beside the oxide of B. Thus, for example, nickel cannot act as a protective metal in iron alloys. The protective layer is formed only if A oxidises before the base metal B.

The oxidation products form a dense or a porous layer on the base metal, according to the value of V_0/V_M, i.e., the ratio of the specific volumes of oxide and metal. This layer separates the metal from the oxygen ; further reaction can take place only if the elements in the reaction reach the phase boundary surfaces. Except in special cases, this is rendered possible by diffusion. The further development of oxidation generally depends on one of the following three laws :—

(1) When $V_0/V_M < 1$, as occurs with porous oxide layers, diffusion is virtually unimpeded, and oxidation increases. The layer thickness y increases linearly with time t, and can be represented by $y = Kt + A$, where K and A are constants.

(2) When $V_0/V_M > 1$, a dense adhesive layer is produced, so that diffusion is considerably impeded and oxidation is retarded. The reaction velocity decreases at the phase boundary and further development is in accordance with the relation $dy/dt = K'/y$, so that $y^2 = K't + A$.
This parabolic law is valid as an approximation in many instances. Exceptions are W and Mo, for which the oxide layer, in spite of $V_0/V_M > 1$, provides no protection within certain temperature ranges (MoO_3 and WO_3 are fairly volatile at about 850° C).

(3) At not too high temperatures, the layer thickness increases logarithmically with time (e.g., aluminium) :

$$y = K'' \log (At + C).$$

This relation indicates that electron diffusion can take place only up to a certain thickness of layer, without additional expenditure of energy. Oxidation practically comes to a standstill when this thickness is reached.

Summarising, it can be said that what is known as " scaling " is an oxidising action of a gas on a metallic material, occurring at a moderate rate at high temperature. The attack can occur with or without secondary reactions. The metal may be oxidised by pure oxygen or by oxygen-carrying particles. The build-up of the layer is in accordance with one of the three laws indicated above (or a combination of these, in many cases).

An alloying additive provides protection against scaling, only if the heat of formation of its oxide is greater than that of the base-metal oxide. The protection oxide must not be volatile and its volume must be as large as possible. A minimum content of additive is necessary for the protective layer to be formed. The scale must allow good temperature transmission to the metal core and should prevent diffusion of both oxygen and the base metal in appreciable quantities.

The difficulties occurring in the use of petroleum products as industrial fuels are chiefly due to the sulphur content and the ash content of the fuel-oils. While the detrimental effects of sulphur compounds in fuel oils have been known for some time, those due to oil ashes have been investigated only fairly recently, in connection with gas turbines and high-performance steam boilers. Many papers have been published on this subject, but unfortunately the investigations made have too often been limited to laboratory cases which do not fully apply to practical operating conditions. The factual evidence is very small and somewhat contradictory, so that additional research is necessary.

The effects caused by the sulphur content can be divided into those which are due mainly to H_2SO_4, SO_3, and sulphates, and those attributable to H_2SO_3, SO_2, and sulphites. Further subdivisions can be based on temperature considerations. The sulphur is present in oil as a soluble organic compound. Through combustion, it is oxidised first into SO_2 and then converted into SO_3. The formation of SO_3 from SO_2 is possible owing to the presence of atomic oxygen in the combustion gases and also as a result of catalytic influences of V_2O_5-vapour. Neumann[2] in his investigations of the sulphuric acid contact process, using V_2O_5 and alkali vanadates as catalysts, found that, apart from platinum, V_2O_5 gives the best results. The mechanism of V_2O_5 catalysis can be expressed, according to Neumann, by the following partial reactions :—

$$V_2O_5 + SO_2 \rightleftarrows V_2O_4 + SO_3,$$
$$2\,SO_2 + O_2 + V_2O_4 \rightleftarrows 2\,VOSO_4,$$
$$2\,VOSO_4 \rightleftarrows V_2O_5 + SO_3 + SO_2.$$

CORROSIVE ATTACKS BY H_2SO_4 AND SO_3

Temperatures below the dew point of H_2SO_4: In gas turbines, the condensation of H_2SO_4 at positions with fairly low temperature results in sulphuric-acid corrosion, with the formation of ferric sulphate. In the

authors' experience, this attack occurs uniformly, in preheaters (no pitting), so that with suitable design and maintenance of the machine it is of no special importance.

Temperatures above the dew point of H_2SO_4: In the presence of alkali-containing oil ashes, the possibility exists of the formation of molten alkali-hydrogen sulphates, which serve as adhesives for ash constituents which would not otherwise be deposited. Corrosion and occlusion of the gas-flow paths may occur as a result. According to the authors' experience, sulphate depositions on 18/8 Cr-Ni and 22/20 Cr-Ni steels can lead to increased attacks at high temperatures. The nature of this attack has not yet been fully determined. Laboratory tests in a crucible with liquid sodium sulphate give very contradictory results. Frequently, the attack is an insignificant general surface corrosion, but occasionally considerable pitting occurs, which has led to failure in 48 hours of a specimen 3 mm in thickness. It is not yet possible to state whether with these steels the failures were due to a porous protective oxide layer or to actual sulphur attack, with the formation of iron and nickel sulphides.

However, similar tests with nickel sheets 1 mm in thickness showed pronounced sulphur attack, with the formation of nickel sulphide. Owing to inter-crystalline attack, the nickel sheet broke down completely after 5 hours. The bottom of the crucible contained a number of silvery spherules of nickel/nickel sulphide, and these were also observed on the surface and in the cross-section. The possibility of the reduction of nickel to a sulphide by contact with liquid sodium sulphate should therefore be borne in mind in relation to gas-turbine plants. If, in any part of the plant, liquid slags attain such a thickness as to prevent rapid diffusion of oxygen to the boundary surface, then the reduction of the sulphate is possible, with the formation of iron or nickel sulphide. The effects of such a reduction should be regarded as being equal to those of hydrogen sulphide. This latter has been investigated by Grüber,[3] who found that the melting point of the resultant sulphide mixture is of considerable importance. The sulphides obtained form eutectoids with the following melting points: Iron/iron sulphide, 985° C; nickel/nickel sulphide, 645° C.

CORROSIVE ATTACKS BY H_2SO_3 AND SO_2

Temperatures below the dew point of H_2SO_3: The dew point is so low that H_2SO_3 cannot precipitate under normal operating conditions. Consequently, no special difficulties are to be expected.

Temperatures above the dew-point of H_2SO_3: Investigations by Hartfield[4] of unalloyed, low- and high-alloy steels between 700 and 1000° C, in steam, carbon dioxide, and sulphur dioxide, have shown fairly small differences for all steels, relative to the various gases. Only in the case of a nickel-rich Ni-Cr-iron alloy (60·4% Ni, 11·7% Cr), was an increased attack by SO_2 noticeable, as compared with the other three gases. It can be assumed, therefore, that SO_2 oxidises steels in the same way as air, when the gases contain excess oxygen—always the case in gas turbines.

LIQUID SLAGS

For the study of liquid slags, it is convenient to subdivide the main ash components into sulphates (Na_2SO_4, K_2SO_4, $CaSO_4$) and vanadium oxides and vanadates (sodium vanadates, sodium vanadyl vanadates).

In the solid state, the slags have no destructive effect on steel. If, however, they occur as molten deposits on the material, the conditions for the initiation and development of an attack are far more favourable. Under such conditions, the quality of the steel surface, and particularly the resistance of its natural protective oxide layer to the liquid slag, will be decisive. If this layer is dissolved by the ash, corrosion can take place. Oxygen diffuses through the liquid slag to the surface of the metal and oxidises the steel.

Both sulphate and vanadium ashes can attack highly resistant steels. The action of sulphates has already been considered. Various investigations, particularly those of Amgwerd,[5] have shown that attack by vanadium-containing oil ashes increases as a function of temperature, time, and content of corrosive substances. The alkali content is also important. It is probable that alkaline sodium vanadates not only act directly but also through the alkali-vanadyl vanadates, by facilitating oxygen transmission. The existence of these very unstable compounds can be recognised by the sudden release of oxygen ("spitting") occurring during their cooling. The existence of intermediary forms of Fe-, Cr- and other vanadates has been verified in X-ray investigations.

It is of interest to note that molybdenum-containing steels are subjected to particularly intensive attack by vanadium ashes (extensive pitting). The effect of the vanadium compounds is to form in the oxide layer MoO_3, which sublimes and thus loosens the layer.

In the foregoing, it has been indicated that, in the high-temperature region (i.e., above 350° C), steels are subjected by the combustion gases to an oxidation similar to that occurring in air. It was therefore considered preferable by the authors to defer the investigation of corrosion of heat-resisting steels in gases containing SO_2, in order to concentrate attention on the much more dangerous effects of liquid slags. The usual laboratory procedure for such tests is to immerse, either partly or entirely, the specimens in a crucible containing the corrosive substance. The increase in weight, or the decrease after de-scaling, is determined after completion of the test. This method is applicable only to easily removable active substances, but even in such cases it is frequently unsatisfactory and produces inconsistent results. The determination of the increase in weight, however, is correct only if no flaking occurs and if the excess of corrosive substance adhering to the specimen can be completely removed. Mechanical removal of scale and slag residues gives misleading results. Chemical removal has the disadvantage that in most cases some of the steel will also be dissolved, so that the apparent decrease in weight is too high. The authors, therefore, found it preferable to omit the determination of weight difference and to assess the specimens only visually. Naturally, fine differences in behaviour of various steels cannot then be indicated. However, it was possible to select the materials failing under all conditions and those showing little or no attack. The first tests were made using oil slags with various contents of V_2O_5 and Na_2SO_4, but subsequently the slag components (in particular Na_2SO_4, V_2O_5, and $NaVO_3$) were investigated separately to determine individual effects. In all cases the specimens were only partly immersed in the corrosive substance. The test conditions produce much more pronounced action than in actual gas turbines, because there is more slag per unit area of the specimen than could ever occur in turbine practice.

The peculiar behaviour of certain nickel-containing steels has already been mentioned. In some tests there was insignificant corrosion, whereas in others rapid failure of the specimen occurred. It was found, however, that definite and fully reproducible results could always be obtained with a steel containing 21% chromium. With this steel, a dangerous local corrosion was never observed. It was therefore recommended and used for the lining of metallic combustion chambers. Subsequent practical experience was in complete agreement with the simple laboratory tests. In contrast to this, the nickel steels previously mentioned were unsuccessful.

A test was made in vanadium pentoxide at 900° C, using specimens consisting of 1-mm thick chrome steel plated on a 4-mm thick carrier steel. The chrome

steel had the following percentage composition : 0·10 C, 1·4 Si, 0·3 Mn, 17 Cr, 0·2 Ni, whereas the 4-mm carrier consisted of 0·05 C, 0·8 Si, 0·7 Mn, 17 Cr, 12 Ni, and 0·9 Mo. After 48 hours, the Cr-Ni sheet was completely fouled and destroyed, whereas the chrome steel remained practically unaffected, as shown in Fig. 1. Thus, under conditions which may also occur in a combustion chamber, even a 17% chrome steel is superior to the Cr-Ni steel. The rapid destruction was very probably due to the presence of molybdenum. It was known, however, from other tests on Cr-Ni steels that failure also occurs in the absence of molybdenum, but not to the extent observed.

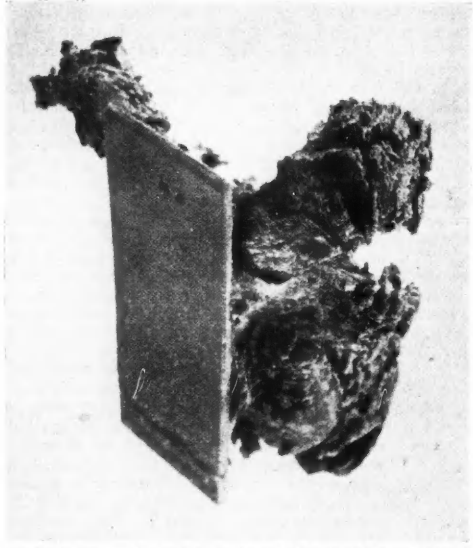

Fig. 1. **Comparative effects of corrosion by V_2O_5 at 900° C after 48 hours. The Cr-Ni carrier plate at the back is completely destroyed, while the chrome steel plating at the front is practically unaffected.**

In further development of the testing method, so as to obtain better differentiation of the behaviour of individual steels, use was made of a so-called thermo-balance. Compared with the crucible test, this instrument has the advantage of making continuous indication possible of all changes to which the specimen is subjected, without requiring removal from the reaction chamber. Continuous tests are thus possible up to 1100° C. The thermo-balance is particularly suitable for investigations of relationships between mass, time, and temperature. One type of test consists in maintaining constant temperature and recording the weight variation as a function of time. This isothermal method is mostly used for solid/gaseous and solid/liquid reactions. The other possibility is to vary the temperature. Thus, weight variation can be determined as a function of time and/or temperature.

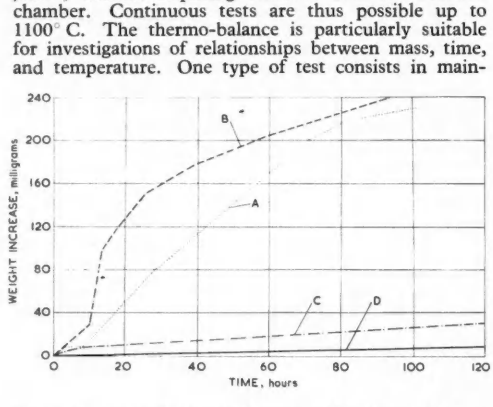

Fig. 2. **Curves for three specimens tested in thermo-balance at 750° C.**

Fig. 2 shows the behaviour of three specimens tested in the thermo-balance at 750° C. Each specimen was tested with $NaVO_3$ (curves *A*, *B*, and *C*). In addition, each specimen was tested with Na_2SO_4 and in air (to obtain reference values). These gave identical results (curve *D*). The percentage composition of the specimens was as follows :—

Specimen	C	Si	Mn	Cr	Ni	Mo	Co	W	Ti	Al
(A)	0·10	0·7	0·5	16	17	tr	—	4	0·8	—
(B)	0·15	1·2	0·6	16	15	0	11	3	1·4	—
(C)	0·03	0·6	0·6	20	75	0	0	0	2·5	+

The differences noted with $NaVO_3$ are illuminating. The fact that the Na_2SO_4 attack coincides with the reference curve in air is not surprising, since Na_2SO_4 melts only at approximately 880° C.

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CONTACTLESS FREQUENCY RELAYS

(*Concluded from page* 96)

closely with the calculated curves, is shown in Fig. 3.

Experiments have shown that the frequency relay has a time lag, owing to the inertia of the vibrating system. Moreover, this lag depends on the frequency and decreases with a drop in frequency below the set value. Experience has proved that the relay is reliable and does not vary with age. Its error does not exceed 0·2% within an interval of input voltage between 1·2

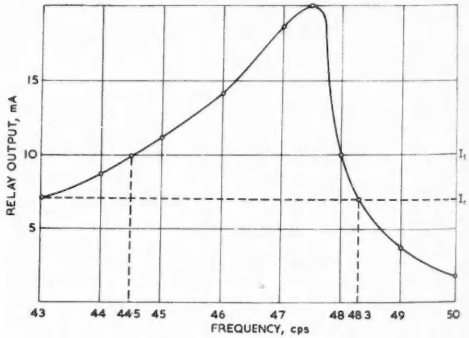


Fig. 3. **Experimentally determined characteristic curve of the vibrator at constant load.**
I_t = Tripping current of output relay.
I_r = Reset current of output relay.

and 0·7 of the nominal value, and even at half the nominal voltage is still below 0·4%. When ambient temperature varies within ± 40° C, the error remains within ± 0·4%. The relay is not affected by temperatures below freezing point. Inclining the relay by up to 10 deg in any sense does not modify the release frequency by more than 0·2%. The power consumed by the relay does not exceed 5 VA.

Some Stall and Surge Phenomena in Axial-Flow Compressors

By M. C. HUPPERT and W. A. BENSER. (From *Journal of the Aeronautical Sciences*, Vol. 20, No. 12, December 1953, pp. 835-845, 12 illustrations.)

In our February issue, phenomena of stall in axial-flow compressors were discussed. This concluding instalment deals with the question of compressor surge.

COMPRESSOR SURGE

Tests of multi-stage axial-flow compressors are conventionally made in test rigs having large inlet and discharge tanks. Violent surge is commonly encountered in these rigs as the compressor weight flow is decreased to a limiting value. This surge is a severe audible pulsation of compressor pressure rise and weight-flow rate, and normally has a frequency of the order of 0·5 to 2 cps, although much higher values have been observed on small rigs. In some jet-engine tests and in multi-stage tests with low receiver volumes, stall with a severe drop in pressure ratio and efficiency has been observed without the audible flow pulsation normally defined as surge. Many investigators have studied the criteria for surge as the criteria for stability, considering the response of the system to small variations from an equilibrium operating point. A continuous pressure-ratio, weight-flow characteristic was implied in these analyses.[1,2]

Classical Surge: In the previously reported investigations, in which the compressor characteristic of pressure rise was assumed to be a continuous function of weight flow for a constant compressor speed, linearisation of the compressor and discharge throttle characteristics and simplification of the external system result in a solution of the differential equation of flow of the following form :

$$\Delta W = K_1 e^{-\alpha t} \sin(\omega t + K_2) \qquad \ldots \qquad (1)$$

where ΔW = the variation of weight flow from the equilibrium value; K_1 = a constant; α = damping coefficient; t = time; ω = a function of the frequency of oscillation; and K_2 = a constant expressing the phase relation.

From this equation it can readily be seen that the damping coefficient α defines the stability of the system, i.e., its response to a small deviation from the equilibrium operating condition. If the damping coefficient has a positive value, the system will be stable. If the damping coefficient has a negative value, however, the system will be unstable and the magnitude of the resulting oscillations will continue to increase until the original assumptions of linearity are no longer valid. The effects of the neglected non-linearity, therefore, will limit the amplitude of oscillation to some finite value, and the cyclic pulsation of surge results. For convenience, this type of surge will be referred to as classical in this paper. It should be noted that the previous analyses[1,2] merely define the conditions of stability. Determinations of amplitudes of flow pulsation are dependent on non-linearities of the compressor characteristics in the stall region, and the procuring of accurate data of this type is difficult because of the existence of compressor surge and rotating stall. When compressor characteristics are discontinuous, however, a different approach to surge analysis may be utilised.

Limit-Cycle Surge: As discussed earlier in this paper, single-stage tests have shown pressure-ratio, weight-flow characteristics which are discontinuous at stall (Fig. 2).* This characteristic indicates that, as weight flow is even slightly decreased below the value for stall, the pressure ratio drops discontinuously to the lower branch of the curve. Further decreases in weight flow, however, cause a continuous change in pressure ratio. Once stall has been encountered, the flow must be increased beyond the initial value for stall in order to relieve the stalled condition. Discontinuities in stage curves cause discontinuities in overall pressure-ratio curves for multi-stage compressors. Double-branch performance curves have been obtained in one multi-stage compressor test in which a small discharge receiver volume was used, and also in a research jet engine.[3] Operation on the stalled branch of the compressor characteristic apparently did not result in the classical instabilities of surge. These compressors, however, surged violently when operated in standard component test rigs with large receiver volumes. Inasmuch as the compressor characteristics on the stalled branch of the curve apparently satisfied the stability requirements of eq. (1), the question arises as to the reason for violent surge when large receiver volumes were utilised. The discontinuity in pressure associated with stall will undoubtedly result in a damped, transient flow-rate fluctuation if normal stability requirements are satisfied. If, however, the compressor flow rate reaches or exceeds the value for stall recovery during the transient, the stall condition will be relieved, and the compressor will again seek equilibrium at the original point of stall on the upper or unstalled branch of its characteristic. Cyclic stalling and unstalling of the compressor, resulting from transient flow variations following an initial stall, thus provide a mechanism for surge. The discontinuous-type compressor characteristic, therefore, suggests solving the differential equation of motion for the compressor and external system for the transient flow-rate response to a step change in compressor discharge pressure at stall.

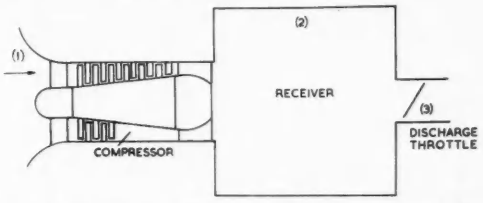


Fig. 6. **Compressor and system considered in surge analysis.**

For the analysis of surge in a compressor with a discontinuous pressure-ratio, weight-flow characteristic, the simplified system indicated in Fig. 6 is considered, in which there are a compressor, discharge receiver, and discharge throttle. The compressor draws air from the atmosphere at station (1) and discharges to the receiver, station (2). The flow is then discharged through the outlet throttle to station (3). The compressor characteristics and throttle characteristics are linearised, as shown in Fig. 7. The upper or unstalled branch of the pressure characteristic has a negative slope and stalls at point O. The pressure drop at stall is represented by ΔP_s, and the lower or stalled branch of the characteristic curve is assumed to have a zero slope. For this analysis, the throttle characteristic passes through the compressor stall point indicated by O in Fig. 7. The increment of weight flow between the stall point and the intersection of the throttle line and the stalled branch of the compressor curve is defined as ΔW_s. The flow must be increased above the original stall value by an increment ΔW_{sr} to permit stall recovery. On the basis of the surge criteria previously discussed, this system is stable on the upper or unstalled branch of the compressor characteristic except at the stall point O.

**The Engineers' Digest*, February, 1954, page 58.—Editor, E.D.

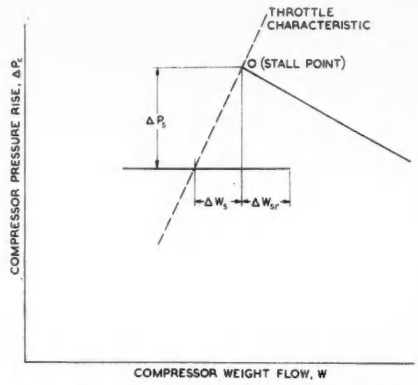


Fig. 7. **Linearised compressor and throttle characteristics.**

The system is also stable on the lower or stalled branch of the compressor characteristic. In the solution of the system differential equation, the compressor is assumed to be operating at the stall point O, and a step change in pressure ratio is imposed. This results in a receiver pressure which is greater than the compressor is capable of producing in the stalled condition, and the solution of the linearised flow equations for the resulting flow variation with time is of the following form :—

$$\Delta W = - \mid \Delta W_s \mid [1 + e^{-\alpha t} (A \sin \omega t - \cos \omega t)] \quad (2)$$

where ΔW = the variation of weight flow from the initial or stall value ; $\mid \Delta W_s \mid$ = absolute value of the weight-flow increment between equilibrium points on the upper and lower branches of the compressor characteristic ; α = the damping coefficient determined by compressor and system characteristics ; t = time ; A = a constant determined by compressor and system characteristics ; and ω = a system constant determining frequency of oscillations.

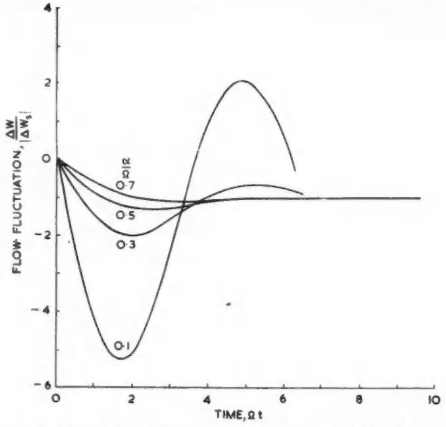


Fig. 8. **Transient flow-rate fluctuations following stall.**

It may be noted that if the weight flow at the intersection of the throttle curve and the stalled branch of the compressor curve is taken as the base for determination of ΔW, the above equation may be expressed in the same form as eq. 1. The magnitude and stability of the resulting flow oscillation are dependent on the magnitude and sign of the damping coefficient α.

Solutions to the above equation have been computed for various compressor and system characteristics, and the results are presented with dimensionless variables in Fig. 8. The ordinate for this plot is $\Delta W \div \mid \Delta W_s \mid$, or the ratio of the weight-flow increment at any instant measured from the equilibrium point on the unstalled branch of the compressor curve to the absolute value of the difference in weight flow between the equilibrium point on the unstalled and the stalled branch. The variable of time is made dimensionless by multiplying it by a characteristic frequency (or dividing it by a characteristic time). The undamped natural frequency Ω of the compressor and receiver acting as a resonator was selected as the characteristic frequency for this presentation, and, accordingly, Ωt is used as the abscissa for Fig. 8. Similarly, the damping term α, which has the dimensions of frequency and is inversely proportional to the time constant of the receiver and throttle, is divided by Ω to provide the dimensionless parameter α/Ω. The variation of $\Delta W \div \mid \Delta W_s \mid$ with Ωt is presented for values of α/Ω of 0·1, 0·3, 0·5, and 0·7. Negative values of the ratio $\Delta W/\Delta W_s$ represent decreases in flow from the initial or stall point, and positive values represent increases. For small damping, α/Ω equal to 0·1, the flow decreases, then increases to a value greater than the stall value, and then decreases again. If the flow increases above the value for stall recovery $\Delta W_{sr} / \mid \Delta W_s \mid$, the compressor's ability to develop pressure will increase discontinuously to the upper or unstalled branch of the curve. A similar computation for a step increase in pressure would indicate a sharp increase in flow rate, followed by a decrease to the value for stall, and the cycle would repeat. Inasmuch as the main purpose of this computation is to study the potential of surge due to cyclic stalling and unstalling, only the overshoot on the stalled branch of the compressor curve was considered, and the transient following the step increase in pressure resulting from stall recovery was not computed.

This cyclic-type operating condition, caused by a step change in pressure ratio due to complete compressor stall, has been defined as limit-cycle surge. This type of surge will result in violent oscillations of flow and pressure ratio. Because of inertia and capacitance effects of the system, the receiver pressure change will lag the flow change during the transient. Reference to Fig. 8 will show that, for larger values of α/Ω, such as 0·3 to 0·7, the transient flow fluctuations damp out rapidly and the compressor point converges on the intersection of the throttle line and the stalled branch of the compressor characteristic ($\Delta W / \mid \Delta W_s \mid = -1$), and limit-cycle surge will not result. From a consideration of discontinuous pressure characteristics, therefore, limit-cycle surge due to complete compressor stall may or may not occur, depending on the magnitude of the system damping.

It can be seen that two types of surge are possible, i.e., classical surge resulting from system instabilities for a compressor with a continuous characteristic curve, and limit-cycle surge resulting from a discontinuity of the compressor characteristic. If the system damping is sufficiently high at the equilibrium point on the stalled branch, compressors with discontinuous characteristics may simply stall without surging. Classical surge may, however, exist as a result of negative damping on either the unstalled or stalled branch of a double-valued compressor characteristic, and the resulting instabilities may incite a limit-cycle-type surge.

Effects of System Characteristics on Damping Coefficient: From the preceding analysis, the importance of system damping on compressor surge or stall characteristics is evident. Consideration must, therefore, be made of the effects of system characteristics on the magnitude of the damping coefficient. If the receiver and throttle have a large time constant, i.e., if the discharge volume is large or the throttle curve slope is large, or both, as is the case for most compressor

(*Concluded on page* 107)

Air-Lubricated Bearings

By H. DRESCHER. (From *Z.VDI*, Vol. 95, No. 35, December 11, 1953, pp. 1182-1190, 38 illustrations.)

Atmospheric air as a lubricant under hydrodynamic conditions has the disadvantage of very low, but the advantage of constant, viscosity. Fundamental investigations are therefore simplified. Load-carrying capacities are very small, though speeds may be high, provided that dynamic instability is prevented. The range of applicability of air-lubricated bearings is still uncertain.

THE viscosity of air changes very little with temperature (Fig. 1), and is therefore practically constant during tests; hence, experimental results can be correlated more easily with theory than can results from oil-lubrication tests. In general, air-lubricated bearings are not fundamentally different from oil bearings. On the other hand, the hydrodynamic gap in air lubrication is extremely narrow, so that the influence of small changes in design and inaccuracies in machining on bearing performance can be studied in great detail.

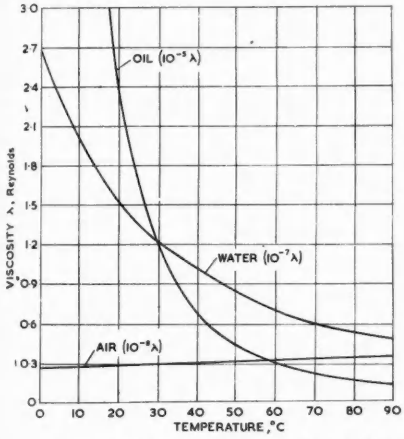


Fig. 1. **Viscosities of air, water, and ordinary lubricating oil.**

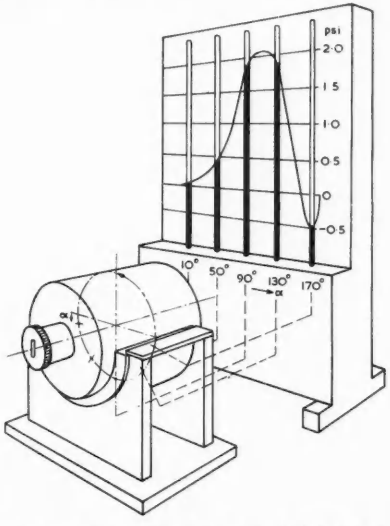


Fig. 2. **Schematic layout for testing air-lubricated half bearings with multiple manometers for measuring air-film pressure on shell.**

α = peripheral bearing angle in direction of shaft rotation.

The importance of tests on air-lubricated bearings thus reaches beyond their immediate applicability, which must always remain limited because of their small load-carrying capacity.

JOURNAL BEARINGS

The following are preliminary results of an extensive investigation into full and half bearings of 120 mm (4·72 in.) length and 120 mm (4·72 in.) diameter. Fig. 2 illustrates schematically the test arrangement; the hydrodynamic air pressures are measured and run-out tests carried out. These indicate (Fig. 3) that

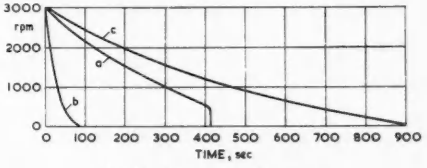


Fig. 3. **Run-out test curves.**

(*a*) Air-lubricated rotor on half bearing (see Fig. 2).
(*b*) Rotor of the same weight and mass moment of inertia as that used for curve (*a*), but running on two greased self-adjusting ball bearings of 1·18 in. diameter.
(*c*) Same rotor as in curve (*b*), but with thoroughly degreased ball bearings.

friction is small, as long as the air film is continuous, but that the shaft stops fairly abruptly once contact between faces has been established. Nevertheless, even during boundary lubrication conditions, hydrodynamic pressures are generated, and can be measured. When a few drops of oil are put on the journal, the higher viscosity so increases friction that the rotor is stopped within a few seconds. Air-pressure distribution is shown for a half bearing in Fig. 2, where a small region of negative pressure can be noticed. In the full bearing, both negative and positive pressure regions actively support the shaft, as shown in Fig. 4, where pressure curve *a* has been measured and curve *b* has been calculated using bipolar co-ordinates; oil-lubricated bearings have no effective negative pressure regions.

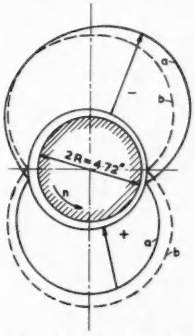


Fig. 4. **Pressure distribution in the centre of an air-lubricated full bearing.**

Length L = 4·72 in.; diameter $2R$ = 4·72 in.; relative radial clearance r/R = 0·0007; speed n = 5350 rpm; Sommerfeld number So = 0·24.

(*a*) measured distribution;
(*b*) theoretical distribution.

+ = positive pressure; — = negative pressure.

The frictional moment may be determined either from the slope at any point of the run-out test curve or from the reaction moment exerted by the bearing shell on a dynamometer balance. The product of the angular deceleration represented by the slope of the run-out curve and the mass moment of inertia of the

rotor gives the decelerating frictional moment M. If the reaction moment of the bearing is measured and the frictional moment M referred to the shaft centre, a correction factor Pe_x must be added to account for the displacement of the shaft in the bearing. The total (vertical) bearing load P is normally known, but the horizontal component e_x of the shaft displacement from the bearing centre must be measured. The correction factor may be of the same order of magnitude as the required frictional moment M. The results of measurements are given in the non-dimensional graph

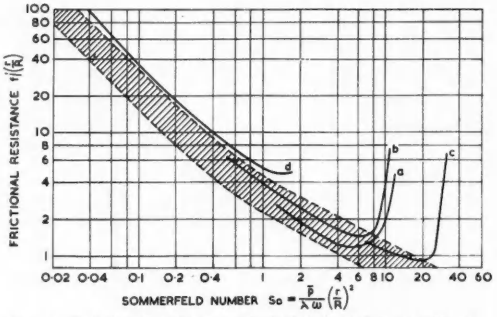


Fig. 5. **Frictional resistance of air-lubricated journal bearings, calculated from measurements of frictional moment.**
(*a*) Half bearing (gunmetal), $2R = 4{\cdot}72$ in., $L = 4{\cdot}72$ in., $r/R = 0{\cdot}001$;
(*b*) full bearing (gunmetal), $2R = 4{\cdot}72$ in., $L = 4{\cdot}72$ in., $r/R = 0{\cdot}0007$;
(*c*) full bearing (steel), $2R = 4{\cdot}72$ in., $L = 4{\cdot}72$ in., $r/R = 0{\cdot}0009$;
(*d*) full bearing (bronze), with compression recesses, $2R = 3{\cdot}37$ in., $L = 3{\cdot}62$ in., $r/R = 0{\cdot}0005$.
Shaded region indicates general hydrodynamic lubrication.

in Fig. 5, where f is the coefficient of friction (tangential friction force M/R divided by total bearing load P), R the nominal radius of the bearing, r the radial clearance, $p = P/(2RL)$ = the mean bearing pressure (= total load/projected area), λ the viscosity of the lubricant, and $\omega = n\pi/30$ = the angular velocity of the shaft. The region of hydrodynamic air lubrication to the left of the minima of curves *a* to *d* coincides with the general (shaded) region of hydrodynamic lubrication for other lubricants* ; even the minima of the curves, i.e., the transitions from boundary to hydrodynamic lubrication, are similar or those of other lubricants. Friction is slightly lower in the half bearing (curve *a*) than in the full bearing (curve *b*).

*G. Vogelpohl, "Dimensional similarity of friction in sliding journals and the lower limit of friction" (in German), *Z.VDI.*, Vol. 91, 1949, pp. 379-384.

THRUST BEARINGS

Wedge-type thrust pads cannot be used for atmospheric air lubrication, as the necessary contour for the very thin air film cannot be machined accurately enough. However, another type, the thrust washer with "compression recess", has proved satisfactory for air as well as for oil lubrication. Fig. 6 shows its principle :—Air is drawn through grooves *e* into shallow recesses *I* to *VI* in the moving or stationary face, where it is compressed so as to separate the thrust faces. The bearing is installed in a vertical asynchronous motor with internal stator *a* and external rotor *b* supported by the thrust washer *d* and rotating at 2865 rpm in an outer air-lubricated radial bearing *c*, so as to combine a high rubbing speed with low specific load, these being conditions favourable for air lubrication. The hydrodynamic pressure in and around one of the shallow recesses (*IV*) has been measured with a manometer. In the recess the air pressure is appreciably greater than that of the surrounding air (Fig. 7). The pressure rises almost linearly (curve *b*) towards the outer edge of the recess, whereas in an oil wedge the rise in pressure is concentrated near the narrowest part of the gap. A lengthening of the oil wedge, therefore, contributes little to the load-carrying capacity of the bearing ; in the case of air-lubricated bearings, however, lengthened recesses distribute the load on the air film and increase its capacity. Thrust bearings with only two recesses have been run successfully.

A three-dimensional hydrodynamic theory has been developed which predicts the pressure rise, frictional moment, thickness of air film, etc., in thrust bearings and permits the selection of optimum dimensions. For the bearing shown in Fig. 6, this theory predicts a film thickness of $0{\cdot}064 \times 10^{-3}$ in. at the transition from boundary to hydrodynamic lubrication, which has been found to occur at 1200 rpm, and a film thickness of $0{\cdot}256 \times 10^{-3}$ in. at its maximum speed of 2865 rpm. The intermediate lift of the rotor (theoretically $0{\cdot}192 \times 10^{-3}$ in.) was measured by Solex pneumatic gauges and was found to be $0{\cdot}160 \times 10^{-3}$ in. The surface roughness, which is not included in the theory, obviously determines the conditions of boundary lubrication.

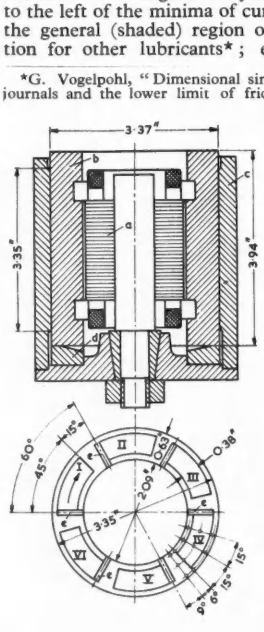
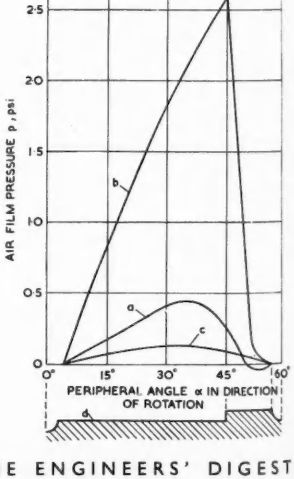


Fig. 6 (left). **Section of asynchronous motor with external rotor and plan view of thrust bearing.**
(*a*) = Stator ; (*b*) = rotor ; (*c*) = bearing ; (*d*) = thrust washer ; (*e*) = radial grooves in thrust washer ; *I* to *VI* = compression recesses, 0·0016 in. deep. The region *IV* contains holes for manometric measurement of air film pressure.

Fig. 7 (right). **Distribution of film pressure in one compression region of the thrust bearing shown in Fig. 6, with $n = 2865$ rpm.**
(*a*) Curve of measurement near the outside of the thrust washer ;
(*b*) curve of measurement along the centre line of the recess ;
(*c*) curve of measurement near the inside of the thrust washer ;
(*d*) contour along the centre line of the recess.



For changing direction of rotation, the air thrust bearing may be provided with recesses for either direction. However, the resulting loss of space and hydrodynamic energy is better avoided by the provision of an intermediate thrust washer with recesses on both faces. Each face then serves as a thrust face for one direction of rotation and exerts a suction effect when rotating in the opposite direction. Thus, only the correct face is automatically used, the other side adhering by suction to the corresponding rubbing face. The load-carrying capacity of air thrust bearings can be increased, and boundary lubrication on starting and stopping entirely avoided, if pre-compressed air is supplied to the recesses.

HIGH-SPEED JOURNAL BEARINGS

The low viscosity of air requires high rubbing speeds to produce a hydrodynamic effect. At very high speeds, however, or rather at low values of Sommerfeld's number (below 0·5), the eccentricity of the shaft axis in the bearing may be so small that any disturbance of equilibrium between bearing load and carrying-film forces will result in oscillations in the shaft displacement and consequently will destroy the load-carrying capacity of the air film.

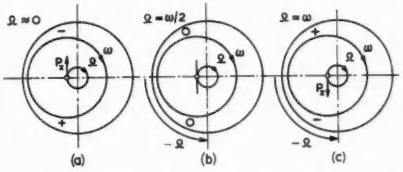


Fig. 8. **Diagrams illustrating the instability of a shaft in a plain cylindrical bearing at small values of the Sommerfeld number.**

ω = Rotational speed of shaft;
Ω = rotational speed of eccentric motion of shaft axis;
P_z = additional force due to lubricating film.
+ = positive pressure; — = negative pressure.

Assume, for instance, that the shaft rotates clockwise at a speed ω, that the bearing load $P = 0$, and that the axis of the shaft has suddenly been displaced to the left of its original equilibrium position in the centre of the bearing (Fig. 8a). In its new eccentric position the rotating shaft tends to create a lubricating film with compression (+) below and suction(—) above the horizontal centre line. An upward force P_z results and tends to force the axis, not towards its equilibrium position, but perpendicularly, in an eccentric clockwise motion Ω about the centre of the bearing; at high rubbing speeds this movement of the axis will be pronounced. On the other hand, now assume that an eccentric mass in the rotor forces its axis to travel clockwise about the bearing centre with a speed $\Omega = \omega$ (Fig. 8c). Since the action of the lubricating film depends only on the relative motion of shaft and bearing, the shaft may be considered to be stationary and the bearing shell to rotate anti-clockwise at a speed $-\Omega$. Obviously, the formation of a lubricating film now produces a downward force P_z, i.e., a force retarding the clockwise rotation of the shaft centre. Finally, if the axis of the shaft is somehow forced to travel clockwise at a speed $\Omega = \omega/2$ (Fig. 8b) and the ensuing relative motion is investigated by again fixing the position of the axis in space, a rotation $+\Omega = \omega/2$ for the shaft against a rotation $-\Omega$ for the bearing shell will be obtained. The shell then removes the lubricant attracted by the shaft, so that a continuous pressure film cannot result. Since $P_z = 0$, the position of the axis will be indeterminate and unstable if disturbed. The upward force P_z tends to accelerate the eccentric motion of the axis, and for $\Omega > \omega/2$, the downward force P_z tends to retard it, until the unstable speed $\Omega = \omega/2$ is reached and the lubricating film breaks down. This is merely a rough picture, but it serves to show that, at high speeds and with small eccentricities, the proper operation and safety of plain journal bearings can be seriously endangered.

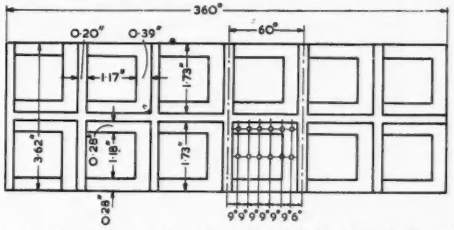


Fig. 9. **Developed contact face of a full bearing shell with stabilising recesses 0·0008 in. deep.**
Diameter of bearing = 3·37 in. Holes for manometric measurements are shown in bottom half.

Stability at high speeds is guaranteed only when the displaced shaft generates forces which press it directly back into its equilibrium position. In the following tests, the motor shown in Fig. 6 was supplied with varying voltage and frequency and run at different speeds up to 12,500 rpm. Compression recesses, similar to those in the air thrust bearing, were cut in the shaft or the shell and served as stabilisers (see Fig. 9). No tests have yet been undertaken with other forms of stabilising planes, e.g., those used with oil bearings. Considering once more the three types of relative motion between shaft and shell (Fig. 8a-8c), a positive pressure with a stabilising influence is obtained, as long as there is a rubbing motion in the sense indicated. In fact, with a plain cylindrical bearing and a vertical position of the axis, disturbing oscillations started at 4500 rpm; with a plain bearing and horizontal rotor, i.e., with a small bearing load P, disturbances started at 7800 rpm and became so violent that continuous operation was no longer possible; with a recessed bearing shell, however, running was entirely undisturbed even at 12,500 rpm. Since the same rotor was used in all these tests, the disturbance could not be

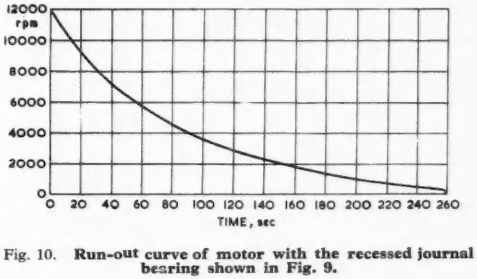


Fig. 10. **Run-out curve of motor with the recessed journal bearing shown in Fig. 9.**

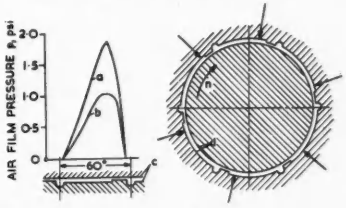


Fig. 11. **Distribution of film pressure in one compression region of the recessed journal bearing shown in Fig. 9, at a speed of 2870 rpm, and with the axis vertical.**

(*a*) Pressure distribution along centre line of recess;
(*b*) pressure distribution along edge of recess;
(*c*) developed contour of rubbing faces *d* along centre line of recess.

due to any eccentric mass but only to the instability of the lubricating film. The frequency of the disturbing oscillations was measured by means of a special arrangement and actually found to be half the running speed. The stabilising effect of the recesses proved to be the same, whether they were cut in the shaft or the shell.

Run-out tests with a recessed shell (Fig. 10) illustrate the smooth running obtained, even at high speeds. The frictional resistance calculated for various speeds from this curve is indicated by curve *d* in Fig. 5, and shows that friction is higher for a recessed bearing than for a plain bearing.

Transition to boundary lubrication also occurs at lower values of the Sommerfeld number *So*, so that the recessed bearing carries less load than the plain bearing. Undisturbed operation of the recessed bearing, on the other hand, is possible even at *So* numbers below 0·04, whilst plain bearings operate safely down to *So* = 0·5 only. The pressure distribution in and around one of the recessed fields in the shell (see Fig. 9) was measured manometrically and the results for the vertical rotor are shown in Fig. 11. An equal pressure is exerted by each recess on the circumference of the bearing, so that even a concentric rotor (zero transverse loading) is held in its equilibrium position by a star of six radial compressive forces. In similar circumstances, no pressure at all can be generated in the plain bearing. Similar manometric measurements were taken on the motor in a horizontal position; the measuring field was displaced each time by 60 deg, so that consecutive film pressures were obtained for the whole circumference (Fig.12), and the compressive force could be calculated for each field. The resultant force, determined from the schematic arrangement of the bearing, in fact balances the deadweight of the rotor (see force polygon). In the plain bearing, suction and compression forces

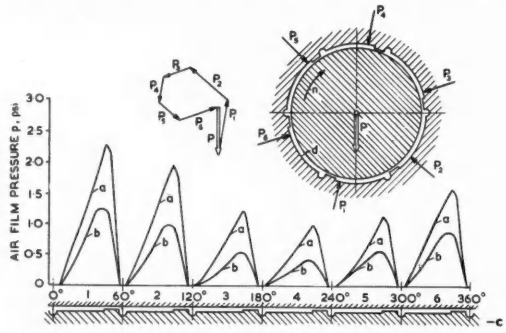
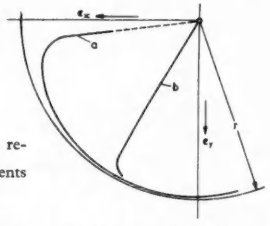


Fig. 12. **Force polygon, cross-section through bearing, and pressure distribution in the developed bearing shell shown in Fig. 9, at a speed of 2890 rpm, and with the axis horizontal.**

(*a*) Pressure distribution along centre line of recess;
(*b*) pressure distribution along edge of recess;
(*c*) developed contour of rubbing faces *d*;
P = total bearing load = weight of rotor = 6·2 lb;
P_1 to P_6 are resultant film forces in the compression regions 1 to 6.



(*a*) Plain cylindrical shell;
(*b*) shell with compression recesses;
e_x, e_y = co-ordinate components of shaft displacement;
r = radial clearance.

Fig. 13. **Displacement diagrams of air-lubricated full bearings.**

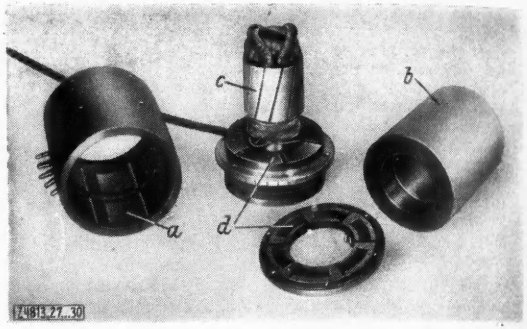


Fig. 14. **Details of motor with external rotor.**
The outer shell (*a*) carries compression recesses for the stabilisation of the rotor (*b*), which is slipped over the stator (*c*) and rests with its end faces against recessed thrust bearings (*d*).

combine to support the rotor, whilst the recessed bearing exerts compressive forces only.

Provisional measurements of the shaft displacement by means of a Solex gauge show that the recessed bearing has a far smaller horizontal component of displacement than the plain bearing (Fig. 13). Nevertheless, the angle between the vertical force and the displacement is still about 30 deg, so that an eccentric motion of the shaft centre still seems possible at very high speeds (see also Fig. 8a-8c, where the angle has been assumed to be 90 deg). However, these measurements were taken on a bearing with a fairly wide plain circumferential portion; if the whole bearing surface is covered with recesses, the angle may be much less than 30 deg. A different asynchronous motor with two air-lubricated recessed journals of 2·68 in. diameter failed above 20,000 rpm because accidental contact between the rubbing faces invariably caused seizure. With bearings reduced to 1·65 in. diameter, the motor was safe, even at 30,000 rpm. It thus seems advisable to increase the stabilising forces in the air film when rubbing speeds exceed 230 fps, for instance, by recesses supplied with compressed air. Recessed thrust bearings ran satisfactorily even above 30,000 rpm. Fig. 14 shows an example of recessed thrust and journal bearings actually made.

APPLICATIONS

Air-lubricated bearings must be manufactured very accurately and must be completely dust-proof. The rotors must be balanced very carefully, if possible already mounted in their proper air bearings. Where there are several bearings in series, these must be aligned with extreme care. The small load-carrying capacity can be compensated only to a small extent by large dimensions. On the other hand, air-lubricated bearings are useful where the presence of lubricating oil must be avoided; moreover, the viscosity of air does not decrease at very high temperatures. The permissible loading may be estimated roughly as follows:—Fig. 5 shows that the highest safe value of the Sommerfeld number is about 5. The specific radial clearance may be assumed to be $(r/R) = 10^{-3}$. With air = $0{\cdot}2 \times 10^{-3}$ Poise or approximately 3×10^{-3} reyns (Fig. 1), a permissible average bearing pressure $p = 15 \times 10^{-3}\ \omega \approx 1{\cdot}5 \times 10^{-3}\ n$, or 4·5 psi at a speed of 3000 rpm is thus obtained. A similar oil-lubricated bearing may sustain average pressures up to 4500 psi at 3000 rpm.

The following experimental installations have been equipped with air-lubricated bearings:—(1) An asynchronous motor of 4 kW, 3000 rpm, as shown in Fig. 15, having large bronze bearing shells and steel bushings on the rotor shaft, after one year's nearly continuous operation was coupled to a d.c. generator, also fitted

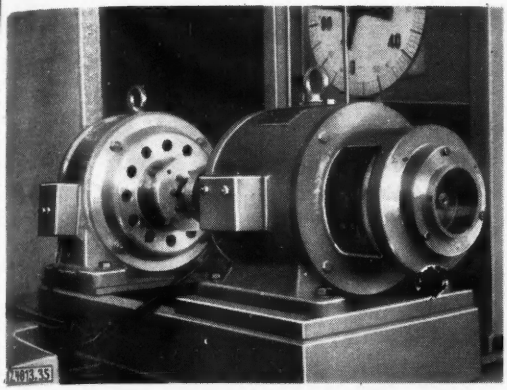


Fig. 15. **Rotary converter, with motor as well as generator supported on air-lubricated journal bearings.**

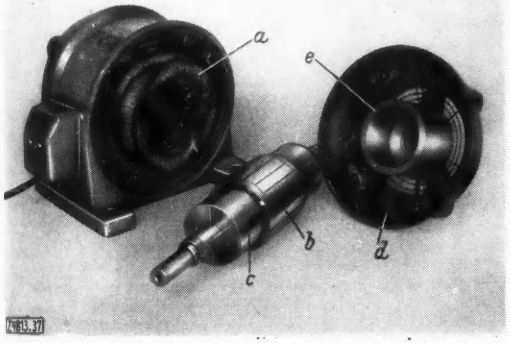


Fig. 16. **Main details of a squirrel-cage motor with air-lubricated journal and thrust bearings.**
(*a*) Housing with field winding ; (*b*) rotor ; (*c*) journal with recessed end faces ; (*d*) end cover ; (*e*) bearing shell for journal (*c*).

with air bearings. An extremely flexible coupling prevents any transverse forces on the bearings and reduces the loading to a minimum. The axial position of the rotors is ensured by the magnetic field, and two plain end discs limit any axial displacement when the current is switched off. This set has been operated for two years as a Ward-Leonard drive. (2) An optical filter for experimental investigations had to be rotated without vibration at about 3000 rpm. A motor with a hollow shaft on large air bearings so reduced the chatter of the previous motor, which ran on ball bearings, that the accuracy of the instrument was increased tenfold. Two simple end discs again ensured axial location. (3) The ball bearings of an asynchronous motor of 1·5 kW, 3000 rpm, as shown in Fig. 16, were replaced by steel bushings with recessed end faces and bronze shells for taking up both radial and thrust loads. The motor ran satisfactorily with very small friction. Since contact between rubbing faces occurs only at starting and stopping, the motor was tested in intermittent operation, by means of an automatic time switch, the current being on for 1·5 min and off for 3·5 min, with a run-out period of 3·3 min. After three weeks, one shell eroded and was replaced by a light-alloy shell. No further interruption occurred during six months operation. The initial failure may have been due to insufficiently accurate alignment. (4) In order to test the suitability of air bearings for large electrical machinery, a rotary converter, 16 kW input a.c. to 12·5 kW d.c., has been equipped with air-lubricated journal and thrust bearings (two bearings per machine) and is to be fitted with a flexible coupling, as mentioned above. (5) As journals for high speeds or small loads, e.g., vertical shafts, need stabilising recesses, an asynchronous motor, to be used horizontally and vertically at speeds from 1500 to 12,000 rpm, has been equipped with a recessed journal for testing dynamic disturbances in ball bearings. Its design follows that of Fig. 6; the external rotor is carried throughout its entire length by one air bearing of 5·5 in. diameter, and thrust washers are provided at its end faces. This design avoids difficulties in alignment and eliminates transverse vibrations in the rotor.

SOME STALL AND SURGE PHENOMENA IN AXIAL-FLOW COMPRESSORS

(*Concluded from page* 102)

component test rigs, the damping coefficient will be small, and the compressor will probably surge. It should also be noted that limit-cycle surge may be encountered more readily at high compressor speeds than at low speeds, because of the increase in slope of the throttle curve and also because of the very narrow range of weight flows for which the two branches overlap. Classical-type surge is also more likely to occur at high than at low speeds.

In jet engines the discharge receiver volume is the combustion-chamber volume and is normally small when compared with the receivers used in compressor test equipment. Moreover, the throttling is effected by the turbine nozzle, and the throttle curve is essentially a constant fuel-flow line which has somewhat less slope than the throttles used in compressor test facilities. As a consequence, the compressor in the jet engine will have a relatively large damping coefficient and will tend to stall rather than to surge.

Experimental Considerations: Additional studies of multi-stage characteristics at the stall point and in the stall region are vital for obtaining a better understanding of surge and stall phenomena. Caution, however, must be exercised in obtaining and analysing these data. During operation with overall compressor stall, rapid-response instruments at either the compressor inlet or discharge may indicate large flow variations due to rotating stall, and these fluctuations may easily be mistaken for compressor surge. Phase relations from two rapid-response instruments in a plane normal to the axis of rotation of the compressor will readily identify rotating stall. Furthermore, fluctuations in torque required to drive the compressor will exist during surge, whereas the torque will be relatively constant with stall.

Inasmuch as the flow fluctuations of surge prevent the experimental determination of the slope of the compressor characteristic curve at the stall point, a discontinuity in the compressor characteristic can be found only if surge is prevented ; in other words, the stall characteristics of a compressor cannot be properly determined if stall results in surge.

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Effects of Electric Current Passing Through Rolling Bearings

By O. SCHENK. (From *Der Maschinenschaden*, Vol. 26, No. 11/12, December 1953, pp. 131-135, 12 illustrations.)

In all types of electrically equipped machinery and vehicles, it is possible that roller bearings may be located in the path of electric currents. The effects of the latter need not necessarily be destructive but, to avoid any possible damage to roller bearings and its potentially serious consequences, it is useful to know permissible limits, so that appropriate safeguards may be incorporated in the design of the equipment.

DAMAGE to roller bearings in electrical equipment, caused by passage of current through them, may result when :— (*a*) The load current of an electric locomotive flows through the axle bearings towards the rails ; (*b*) current due to an induced voltage, such as may arise in the shaft of an electric motor, flows through both bearings and the housing ; and (*c*) leakage currents, due to defective insulation and stray currents, flow through the mechanical parts of a machine, or when currents make use of the metallic structure of equipment as a return path.

There are other ways in which current flow may occur ; for instance, an e.m.f. may arise in the bearing itself. This may be observed when the bearing rotates in a magnetic field, e.g., the leakage field of a generator, when the rotating parts cut magnetic lines of force. There is also the rare case when, under stationary conditions, voltages arise at points of contact in the roller bearing ; these may produce corrosion (Richardson effect).

ESTIMATION OF EXTENT OF DAMAGE.

Estimation of the extent of damage in roller bearings, due to currents, is made possible by the large number of cases of damage where detailed investigations could subsequently be carried out. The current density, i.e., the ratio of current strength to the cross-sectional area of the contact surface between rollers and races respectively, is the criterion for the extent of the damage to the materials concerned ; the limiting values of the currents likely to flow can therefore be established. The pressure contact surface in the bearing is derived from the mechanical loading of the bearing, and the size of the rollers, respectively. The calculation of pressure-contact surfaces is based on Hertz's theory of elastic bodies, with the assumption that the limit of elasticity is not exceeded. Typical values for pressure-contact surfaces in a self-aligning axle roller bearing under various mechanical loading conditions are given in Table I, these values being for an axle-bearing of the motor-coach of an electric train. The boxed-in group of figures indicates the danger zone.

TABLE I. EFFECTIVE CROSS-SECTIONS FOR CURRENT FLOW AND CURRENT DENSITIES FOR VARIOUS AXLE LOADINGS.

Axle loading kg	Effective cross-section for current flow mm²	Current density, A/mm², for a current flow of 8 A	10 A	12 A	15 A
1000	5·52	1·44	1·81	2·16	2·69
2000	7·91	1·00	1·26	1·52	1·90
3000	9·60	0·84	1·04	1·26	1·56
4000	11·80	0·72	0·89	1·08	1·35
5000	12·40	0·64	0·80	0·97	1·20

These values show that, with decreasing mechanical loading and consequent reduction in effective cross-section for current flow, the danger of damage increases. This may explain why, in electrically heated trains, the lightly loaded coaches sustain more serious damage to their axle-bearings than the heavily loaded axle-bearings of the electric locomotive or motor-coach. In view of this, modern coaches have been fitted with two-wire circuits for their heating and lighting appliances

Current flow-paths in a single phase a.c. motor-coach unit, fed from an overhead trolley wire, are shown

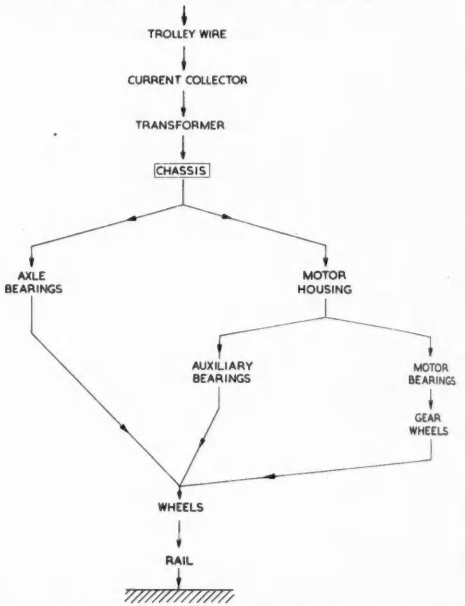

Fig. 1. **Current flow-paths in a single-phase a.c. motor-coach unit, fed from an overhead trolley wire.**

in Fig. 1. In this connection, assuming that the average value of the current flowing through each of its eight axle-boxes is approximately the same, and that part of the current also flows through the auxiliary axle-bearings, then it may reasonably be accepted that there are ten parallel current paths, i.e., that only one tenth of the total load current flows through each axle-box. It has been found in practice and confirmed experimentally that a current density of 2 A/mm² will cause damage ; the time factor must, however, be taken into consideration. The latter is operative on a logarithmic basis, as may be seen from the fact that damage from a current density of 2 A/mm² occurs after 5 hr ; from 1·8 A/mm² after 25 hr ; from 1·7 A/mm² after 50 hr ; and from 1·4 A/mm² after 500 hr. Values below 1·4 A/mm² are not considered to be of much consequence. Based upon the above considerations, a fairly reliable advance estimate of the danger zone can be made.

EFFECTS OF PASSAGE OF CURRENT.

The effects of current flowing through the bearing on the contact surfaces between rollers and races are independent of the frequency or other characteristics of the current. These effects are always first evidenced by pitting, which may be clearly seen with only × 10 magnification. Steel oxidation tints in the craters are also typical. As the effect increases, crater areas, as shown in Fig. 2, may develop ; the influence of temperature on the contact surface where current has passed may readily be observed with a magnification of × 50, as shown in Fig. 3.

Sudden short-circuit currents, as, for example, those close to the low-input impedance current-feedpoints in electric locomotives, may result in discolouration

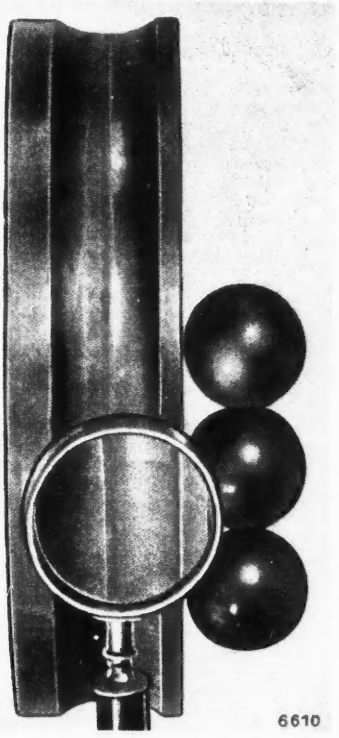

Fig. 2. **Crater areas on the inner race of a ball bearing.**

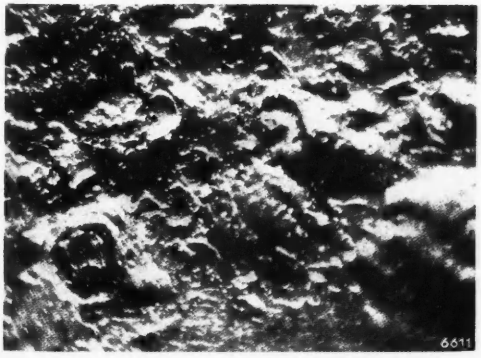

Fig. 3. **Crater area under magnification of × 50.**

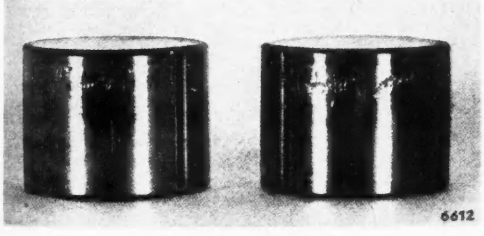

Fig. 4. **Scoring and discolouration caused by current of short duration.**

Fig. 5. **Crater formation and globules of molten metal, caused by high current density.**

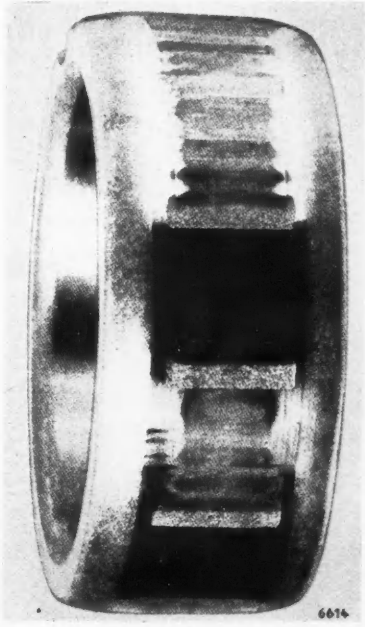

Fig. 6. **Inner race of roller bearing, showing crater formation at intervals.**

and zigzag scoring of rollers, as shown in Fig. 4, or even in the formation of globules, due to localised melting of metal (Fig. 5).

The extent of damage will again depend on the duration of current flow. Similar occurrences were observed during the welding of a coach bogey, where the earth-return lead of the welding set had been connected to the rail; as a result, a welding current of 150 A flowed through the stationary bearings. A similar case of damage to a roller bearing, due to welding current, occurred during repair work to the chassis of a lorry, where the welder had attached the earth terminal to the drive-shaft. Fig. 6 shows the damage to the stationary roller bearing and the crater formation where the rollers were in contact with the inner race; because the drive-shaft had moved slightly in the course of the operation, additional, but somewhat

less severely, damaged areas are discernible at regularly spaced intervals.

A characteristic result of current flow is the formation of ridges on both the rollers and the races, caused by an estimated current density of 2·8 A/mm², as shown in Fig. 7. A further example, that of an axially loaded self-aligning roller bearing from an axle in a d.c. electric train, is illustrated in Fig. 8.

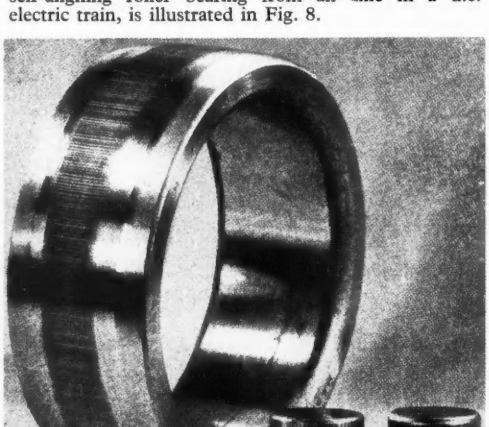

Fig. 7. **Characteristic ridge formation on inner race and rollers.**

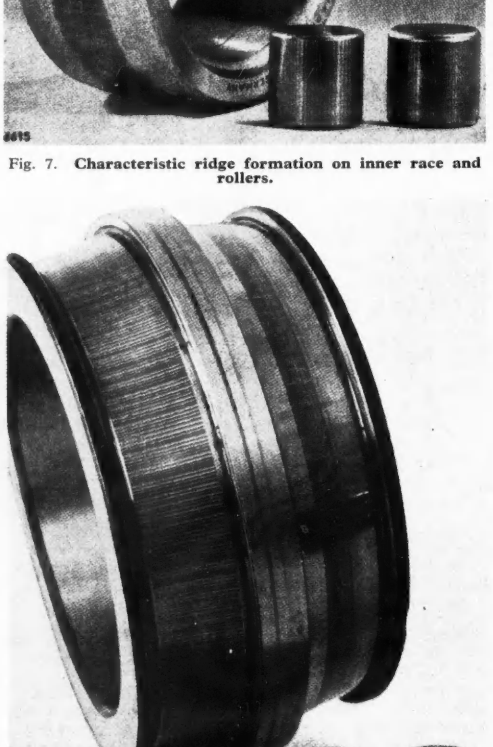

Fig. 8. **Ridge formation on races and rollers of an axially loaded self-aligning roller bearing.**

Several theories on the possible causes of axial ridge formation have been advanced; it is certain that any protracted passage of current results in metal deformation or displacement. Bearing contact surfaces, through which there has been flow of current, show discolouration, ranging from brown to black, generally identified as Fe_3O_4.

It is known that, if a sliding component is added to rolling friction, intermittent contact oscillation may result, and this may be responsible for the formation of ridges between wheel surface and rail. It is thought possible that, in the case of a roller bearing, similar oscillations may arise, so that current flow through the bearing manifests itself only where surfaces have made intermittent contact. Owing to the formation of Fe_3O_4 and the peeling off of oxidised layers, ridges may reach heights of several tenths of a millimetre. The number of ridges formed appears to be independent of the number of rollers, the running speed of the bearing, or the supply frequency. Apart from the rollers and races, the remainder of the bearing is also affected. Experience has shown that the journal and the casing of a bearing damaged by current also show marked discolouration, which, although it may pass for fretting corrosion (Fe_2O_3), is in fact of a much darker colour. This is due to electrolytic effects and to the fact that it is in the process of changing into Fe_3O_4. An example of this type of journal discolouration is noticeable in Fig. 7. Brass ball- or roller-cages may also be damaged.

A great deal of work has been published to-date, with a view to removing the complex causes of differences of potential in motor shafts. It is appropriate to stress the high incidence of cases where asymmetry in the magnetic fields of commutator machines has been the cause. Inadequate maintenance of brush-gear, alterations in the leads to the brush-holders, etc. may well give rise to the flow of unwanted current in the shaft.

Protective Measures.

Protection from the effects of the passage of current may be achieved by fitting electrically insulated roller bearings or by providing an alternative path, so as to divert the current from the bearings. The former method is not always practicable and in some cases this measure would not enable flow of the load current to take place at all. Bearings with insulation surrounding the casing have been made, but the mechanical strength of the insulating material has to be considered with regard to the tolerances prescribed for the fitting of roller bearings. In the construction of electrical machinery, the practice of insulating both bearing brackets from the housing has met with success in the case of voltages induced in motor shafts and resulting current flow. The low voltages arising, which rarely exceed 2 V, fully justify this procedure.

The method of introducing an alternative (i.e., low resistance) path for the flow of current, with a view to bearing protection, is recommended in most cases. Contact ohmic resistances must, of course, be low compared with those of the roller bearing, if the current is to be encouraged to take the alternative path. It must, however, be realized that the provision of an alternative path in effect merely reduces the current density in the bearing; the time which elapses before damage occurs is, however, extended, resulting in longer periods of trouble-free operation.

Generally speaking, damage due to current flow does not often occur, mainly because roller bearings tend to remain unaffected up to certain limits. In the case of electric locomotives, where the load current flows through the axle bearings towards the rails, current values are known beforehand, and protective measures are therefore incorporated into the design. In the case of current due to induced voltage, or leakage currents and stray currents, an effort should always be made to remove the electrical causes of damage.

Design of Ventilation in Turbo-Alternators, Using Scale Models

By D. Kerényi. (From *Elektrotechnika*, Vol. 46, No. 12, December 1953, pp. 341-347, 14 illustrations.)

In the development of electrical machinery, there are at present two main possibilities of improvement, apart from an improvement in the properties of the materials employed. These are the use of better, more durable, and more heat-resistant insulating materials, and the improvement of ventilation. The former permit the use of higher working temperatures, and the latter ensures more efficient and economical removal of the heat generated. This results in a saving in running costs, which may be very appreciable in large electrical machinery.

Hitherto, the design of ventilation for turbo-generators has been based on observations of existing types. This is unsatisfactory for several reasons, and thus has indicated the need for studying the problem of ventilation in some detail. Such a study may be divided into three main fields :—(A) The determination of the quantity of air required for cooling. (B) The determination of the pressure difference required for producing air flow, and its subsequent distribution. (C) The choice of a suitable fan.

(A) The quantity of air required can be calculated when the losses and permissible overheating are known. The latter depends on the heat resistivity of the insulating materials and the heat emissivity of the surfaces. No adequate data are available in the literature, and tests are at present in progress to determine these factors.

(B) The pressure difference required for air flow and its subsequent distribution in the various air channels can be calculated only if the resistance of the channels is known. This latter quantity cannot normally be estimated, and scale-model experiments are indispensable for its determination.

(C) When the required quantity of air, pressure difference, and other data connected with operation, such as speed and space available, have been obtained, the fan can be designed accordingly.

Tests carried out in the laboratories of the Klement Gottwald factory in Czechoslovakia are concerned with problem (B). The object of the measurements was the determination of air distribution in standard Hungarian types of turbo-generators. The data obtained from scale-model experiments will be employed in the design of future types. Many new problems arose in the course of these experiments, which are still being continued.

Similar scale-model tests have been carried out in other countries and, while some of the results obtained are of general validity, others are restricted to turbo-generators of a particular design. The chief difference between Hungarian and other two-pole alternators is that the rotors of the former are of an elliptical cross-section. As other tests have shown that under certain conditions the rotor has a considerable influence on air-distribution and the magnitude of the pressure difference required for circulation, the question arose as to what extent an elliptical rotor cross-section affects ventilation conditions.

As the object of the study was mainly in connection with the differences between elliptical and cylindrical rotors, it was not necessary to provide the scale model with an electrical output. The model was constructed in conformity with the requirements of geometric, kinematic, and dynamic similarity. The ratio of the Reynolds number of the model to that of the alternator was 1 : 4·5, the geometric dimensions being in this ratio, while speeds in both cases were substantially the same. When comparing relative ventilation between rotors of different cross-sections, the difference in Reynolds numbers is of no consequence, but in the study of flow conditions and loss factors Reynolds numbers must be identical.

The model was constructed to simulate a 44 MVA, 10·5 kV, two-pole turbo-alternator. The rotor of the model was constructed of solid iron rings, and the stator of wooden discs of 10 mm in thickness. These correspond to the laminations of the alternator, the ventilation gap between the discs being adjustable by means of bakelite distance pieces. The output from an externally mounted fan was connected to the generator by three ducts, the air entering at the two ends of the alternator through pressure chambers, and at the centre through a removable casing.

The quantity of cooling air could be regulated partly by the speed of the fan, and partly by means of valves. Flow was measured by conventional flowmeters. The quantity of air issuing from the ventilation gaps was measured by a Pitot tube. It was found that the distribution of air speeds along the gap was not uniform ; next to the wall of the lamination it was zero, and it was highest in the middle of the gap. For purposes of comparison, it is immaterial whether the mean or maximum values are plotted, as it was also found that the relation between the mean and maximum air speed was practically independent of the actual speed.

Measurements

The distribution of outflow was examined with three different methods of ventilation, *viz.* :—(1) With the central casing removed, air enters the air gap from the two pressure chambers at the ends, whence it flows out through the ventilating gaps. (2) Air enters the air gap partly from the two ends and partly through the centre casing and the centre set of ventilating slots, as shown in Fig. 1. Outflow takes place through the ventilating slots at both ends. (3) Air is admitted through the central casing only, the ducts leading to the end pressure chambers being closed. This type of ventilation is of less practical interest.

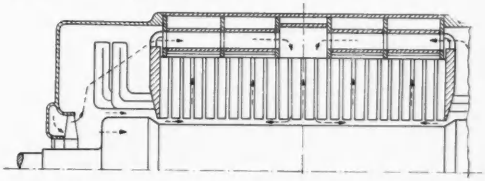

Fig. 1. **Method of ventilation, with air entering the air gap partly from the two ends and partly through the centre casing and centre set of ventilation slots.**

Measurements were carried out with ventilating gaps of 2 and 5 mm, with both stationary and revolving rotors of cylindrical and elliptical shape. Some characteristic air distribution curves are shown in Figs. 2, 3,

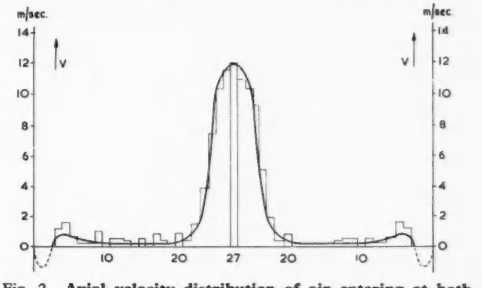

Fig. 2. **Axial velocity distribution of air entering at both ends.**
Width of ventilation gap 5 mm. Cylindrical rotor. Air flow = 0·4 m³/sec.

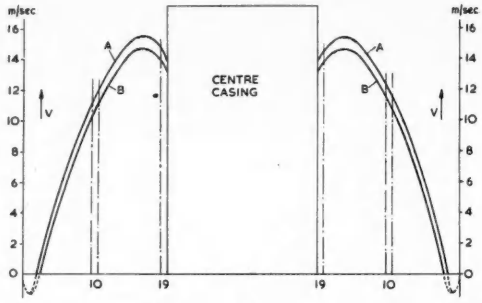

Fig. 3. **Axial velocity distribution of air entering at both ends and at the centre.**
Width of ventilation gap 2 mm.
(A) Elliptical rotor ; air flow = 0·658 m³/sec.
(B) Cylindrical rotor ; air flow = 0·61 m³/sec.

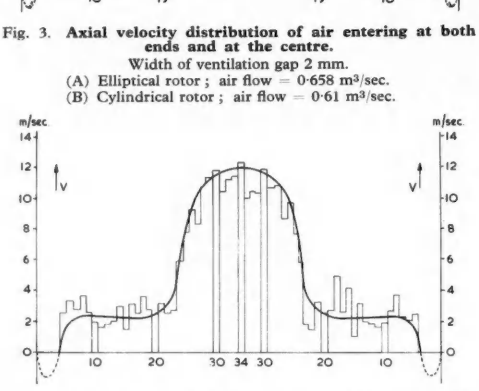

Fig. 4. **Axial velocity distribution of air entering at both ends.**
Width of ventilation gap 2 mm. Elliptical rotor. Air flow = 0·438 m³/sec.

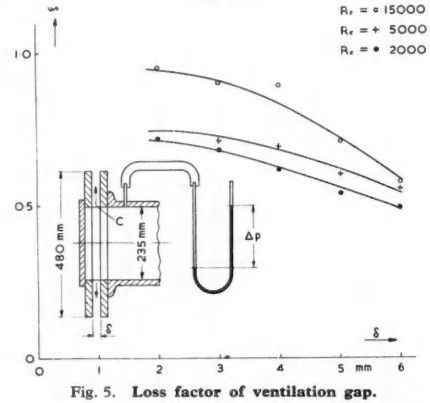

Fig. 5. **Loss factor of ventilation gap.**

and 4. In these diagrams the thickness of the laminations is neglected and the ventilation gaps are numbered from each end towards the centre. The vertical axis shows the flow velocities measured at the centre of each gap. The rotor speed in all cases was 2200 rpm.

The following conclusions could be drawn from the distribution diagrams obtained :—There is no essential difference between elliptical and cylindrical rotors with respect to air flow distribution. Furthermore, in the case of alternators with comparatively large gaps, such as were employed here, it is immaterial whether the rotor is stationary or moving. In the case of air inflow from the ends, maximum outflow is always at the centre. At the ends, a suction effect can be observed at high rates of air intake (dotted part of curves). When air enters at the centre, the maximum outflow is at the ends. A comparison between the results for 2-mm and 5-mm ventilating gaps shows that the distribution is more uniform with the smaller gaps, i.e., a greater gap resistance gives rise to a more uniform distribution. The air distribution can thus be influenced within wide limits by a suitable choice of ventilating-gap widths, or by the appropriate modification of lamination thicknesses. From the practical point of view, the latter is probably the better solution, as then only one type of distance piece need be manufactured.

Correct cooling of machinery implies, of course, not so much an even distribution of cooling air, as one ensuring even temperature distribution within the machine.

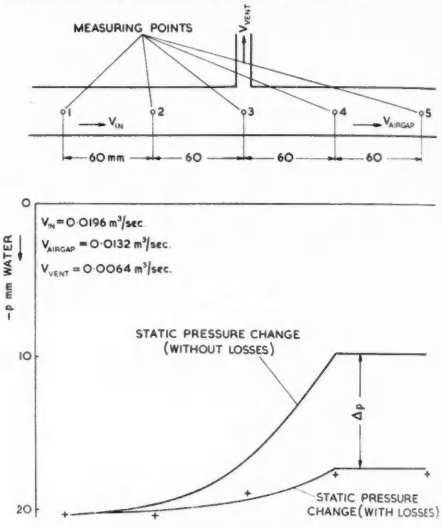

Fig. 6. **Pressure changes in air gap.**
Δp = pressure drop due to losses.

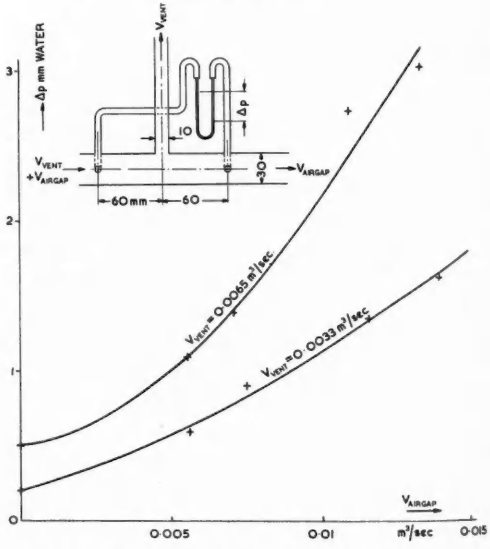

Fig. 7. **Pressure rise at the branch point as a function of air flow in the air gap.**
Δp = pressure difference between points (2) and (4) in Fig. 6.

Little information seems to be available concerning the actual temperature distribution within turbo-alternators, but, in general, heating is greater in the middle than at the ends. A cooling system, whereby more air flows out through the middle section, is therefore a favourable one. However, for each particular design of alternator, the best distribution of cooling air must be separately determined.

From the point of view of reducing the necessary cooling output, it would be advantageous to reduce the air resistance of the cooling channels. It was found in measurements carried out on one of the alternators that about 85% of the pressure drop occurs along the ventilating gaps. The resistance of a single ventilating gap was therefore investigated by means of a separate scale model. The pressure drop within the gap may be expressed as $\Delta p = \zeta \rho C^2/2$, where ζ = loss factor, ρ = density of air, and C = average velocity at the point of entry into gap, calculated from the intake and outlet cross-sections. Fig. 5 shows a section of the model, and the dependence of the loss factor on the width of the gap for different Reynolds numbers.

In this experiment, air enters the gap from a comparatively wide cross-section, and thus the air speed before entry is negligible in comparison with the speed in the gap. This is not so in actual practice, and therefore a further investigation was carried out, to establish the influence of the air speed within the air gap on the quantity of air entering into the ventilation slots, and also the pressure conditions around the point of entry into the ventilation slot. For this purpose another model was constructed, according to Fig. 6, the horizontal channel representing the air gap, and the vertical branch one of the ventilation gaps. The air flow in the two was indepently variable. The pressure distribution curve shows that a pressure rise takes place in the air gap near the branch, but that this rise, owing to losses, is less than that calculated from the average rate of flow from Bernoulli's equation. In the ventilation gap a corresponding pressure drop is observed at the point of entry; this is appreciably greater than the theoretical value calculated without losses. In addition, it was found that the air flow in the gap influences flow in the ventilation gap only to a small extent. This effect, which makes the calculations of air distribution more involved, has therefore been neglected. However, the pressure drop in the air gap, resulting from the outflow of air through the ventilation slots must not be neglected. Fig. 7 shows this drop as a function of the air flow in the air gap, for two different rates of flow through the ventilation gap.

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U. S. A.

The Holding Power of Shrink Fits

By B. TROCK. (From *The Iron Age*, Vol. 172, No. 20, November 12, 1953, pp. 175-177, 2 illustrations.)

The holding power of shrink fits is shown to be dependent on the surface finish of mating parts, radial pressures, and the length of time during which the parts have been fitted together.

EXPANSION of the female part for shrink-fitting often requires heating above its previous tempering temperature, thereby resulting in lower hardness and decreased strength. This difficulty prompted an investigation into shrink fits to determine whether or not large interferences could be safely reduced, thus lowering the temperature required for expansion.

In this investigation, the following test observations were made:—

(1) When interference increased above 0·003 per inch, the added holding power per unit increase in interference was greatly reduced. This suggests there is an optimum value of interference in inches per inch which will give maximum holding power.
(2) The smoother the mating surface the greater is the holding power for a given interference.
(3) The manner of failure is correlated to radial pressure and surface finish.

Radial pressures exerted by shrink fits were calculated for steel rings on solid steel shafts, using Lamé's equation:

$$P = E\, l\, \frac{c^2 - b^2}{2\, bc^2}$$

where P = radial pressure [psi], E = modulus of elasticity [psi], l = half the total interference [in.], c = outer radius of hub [in.], and b = shaft radius [in.].

The axial holding power of a shrink fit was calculated from

$$F = \pi\, d\, L\, f\, P$$

where d = shaft diameter [in.], L = length of contact surfaces of mating parts [in.], f = coefficient of friction (0·3 for steel on steel), and F = minimum force required to separate components [lb].

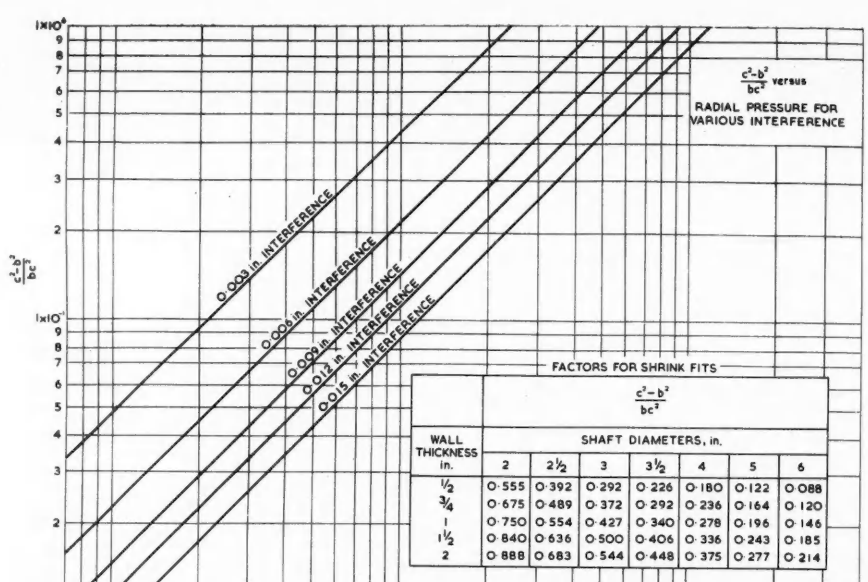
For testing, hub inside diameters of 3·000 in. and 4·000 in. were chosen, and interferences ranged from 0·003 in. to 0·015 in., in steps of 0·003 in. Hub walls were held to 1 in.

For the first series of tests, 10 rings and 10 shafts were made of 4340 steel* quenched and tempered to R_c 32 to 36. Mating surfaces were ground to a finish of 10 to 12 microinches. Rings were furnace-heated to 1000° F, while shafts were cooled to − 110° F. The units were then assembled, and tested after reaching room temperature.

The testpiece was placed on a thick-walled tube with square and parallel ends. A solid steel cylinder, $2\frac{7}{8}$ in. in diameter, was located in the centre of the end of the shaft. The assembly was then placed in a tensile tester of 400,000 lb capacity and the load applied until either the sample failed or the capacity of the machine was reached. A piece was considered to have failed at the load which caused the initial movement. Samples 1, 2, 6, and 7 only failed under the loads shown in Table I. The others showed no movement under the full 400,000 lb load, regardless of the rate of load application. Samples which failed were found to be slightly scored.

For the second series, components for 10 more assemblies were made with ground shafts and machined bores. The shafts had the same finish as before, but the surface finish of the ring bores ranged from 60 to 125 microinches. The material, method of assembly,

*0·38-0·43 C, 0·6-0·8 Mn, 0·20-0·35 Si, 1·65-2·00 Ni, 0·7-0·9 Cr, 0·2-0·3 Mo.



FACTORS FOR SHRINK FITS

WALL THICKNESS in.	$\frac{c^2-b^2}{bc^2}$ SHAFT DIAMETERS, in.						
	2	2½	3	3½	4	5	6
½	0·555	0·392	0·292	0·226	0·180	0·122	0·088
¾	0·675	0·489	0·372	0·292	0·236	0·164	0·120
1	0·750	0·554	0·427	0·340	0·278	0·196	0·146
1½	0·840	0·636	0·500	0·406	0·336	0·243	0·185
2	0·888	0·683	0·544	0·448	0·375	0·277	0·214

Fig. 1. **Graph showing the factor $(c^2 - b^2)/bc^2$ plotted against radial pressure.**

and method of testing were the same as before. Results of the tests are shown in Table II.

Several months after the first series of tests, the six assemblies which had not failed originally were tested as before. All the samples failed at loads under 400,000 lb. (See Table I, samples 3, 4, 5, 8, 9, and 10).

Failure occurred in one of three ways :—

(1) For one group, maximum pressure required for complete separation was that which caused the initial movement. This value dropped sharply to a much lower figure and oscillated there until an appreciable portion of the shaft was exposed, about ¾ in., after which it decreased slowly.

(2) For a second group the pressure, which caused the initial motion rose gradually as the shaft moved out of the ring, reaching a peak value when approximately ¾ in. of shaft was exposed. Pressure then began to decrease steadily.

(3) The third group may be considered a combination of (1) and (2) above. Pressure continued to rise after the initial movement, as in case (2), but after reaching a peak value dropped sharply and began to oscillate at a value below the initial load. This pressure began to decrease slowly after about 1 in. of shaft was exposed, in a manner similar to case (1). Samples failing in this way were Nos. 3 and 8. These two samples differed only in shaft size, the interferences and surface finishes being approximately equal.

TABLE I. GROUND SHAFTS AND BORES

Sample No.	Basic diameter in.	Mean interference in.	Separating force, 1000 lb	
			Actual	Calculated
1	3	0·00287	109	78
2	3	0·00570	170	150
3	3	0·00898	180	243
4	3	0·01205	316	326
5	3	0·01500	333·5	406
6	4	0·00270	60	63·8
7	4	0·00565	120	133
8	4	0·00875	351	206
9	4	0·01160	353·5	274
10	4	0·01445	274	340

TABLE II. GROUND SHAFTS AND MACHINED BORES

Sample No.	Basic diameter in.	Mean interference in.	Separating force, 1000 lb	
			Actual	Calculated
11	3	0·00231	58	62·7
12	3	0·00479	124	130
13	3	0·00710	158	192·5
14	3	0·01060	250	288
15	3	0·01270	250	346
16	4	0·00116	51	27·4
17	4	0·00453	74	107
18	4	0·00920	205	249
19	4	0·01135	270	268
20	4	0·01360	284	321

Analysis of the three types of failure shows that type (1) occurred when either smooth surface finish or low unit radial pressure, or both, were present. Type (2) occurred when high radial pressures were combined with a rough surface finish. These results indicate that possibly the manner in which failure will occur can be predicted if the surface finish and radial pressures are known. However, it will be necessary to establish first the correlation between them.

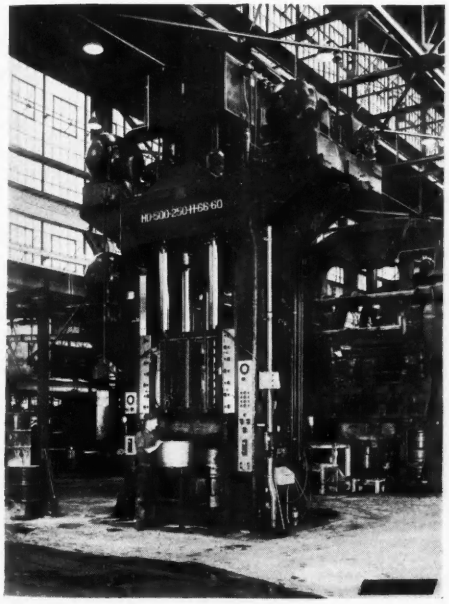
The least expected and most surprising feature of the tests was the decrease in load required to cause failure in samples 3, 4, 5, 8, 9, and 10. These pieces, which originally withstood 400,000 lb pressure at various rates of load application, failed at much lower loads when re-tested approximately eight months later. This result suggests that time is another factor to be considered when designing shrink fits with high radial pressures. However, further testing is necessary for verification.

An examination of Lamé's equation showed that radial pressure was a function of the factor $(c^2 - b^2)/bc^2$ and could be plotted against it as a straight line on log-log paper, as shown in Fig. 1. With this figure, the radial pressure developed in a shrink fit can be quickly determined if the shaft size and hub thickness lie within the scope of the graph.

New Materials, Processes and Equipment

HYDRODYNAMIC PRESS FOR DEEP-DRAWING OPERATIONS

A new addition to the range of presses designed and built by the E. W. Bliss Company, of Canton, Ohio, is a fast, double-action press with many advantages for deep-drawing operations. Controlled drawing speed, slide-within-slide construction, and utilisation of a separate blank-holder pump are some of the outstanding features of the press. The ability to control the uniform drawing speed and the easy control of blank-holding pressures make the machine well suited for deep drawing stainless steels and for other types of double-action press work requiring careful control of pressure and speed.



There is a separate pumping system for the blank-holder, making the blank-holder pressure entirely independent of the punch slide pressure. During the draw stroke, only a small volume of oil is used to sustain the blank-holder pressure. A minimum of power is converted into heat and far less cooling is required than in the case of earlier presses.

ELECTRONIC DIGITAL COMPUTER

The new Consolidated 203 digital computer, manufactured by Consolidated Engineering Corporation, of Pasadena, California, is not limited to any specific field of activity, but is adaptable to almost any problem reducible to numerical terms. Although midway in the price range of digital computers already developed, its unusual speed, capacity, and versatility make it capable of handling not only problems in research and engineering but also those in industry, finance, and commerce.

A magnetic drum, rotating at 3600 rpm, together with the associated reading-writing heads and electronic circuits, serves as the computer's memory. A capacity of 4080 "words" of 10 decimal digits each —a "word" is either a number to be used in computation or a command to the computer to perform some specific operation—plus the speed at which the computer can extract the words from the memory, gives the overall system an appreciable speed advantage. A quick-access memory section of the drum allows access to numbers or commands stored temporarily within it in an average of 0·85 millisecond. Average access time to words stored in the main part of the memory drum is approximately 8·5 milliseconds.

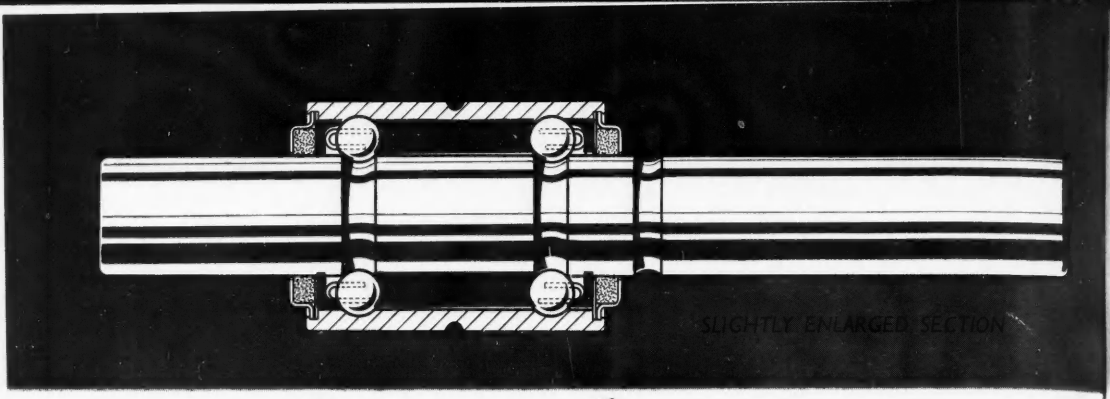
All additions, subtractions, logical shifts, and transfers are performed at an average rate of 500 per second, while multiplications are accomplished at 120 per second and divisions at 85 per second. These typical operational rates include obtaining the 10-decimal-digit words (numbers or commands) from the quick-access portion of the memory.

Accessory equipment includes auxiliary magnetic-tape storage, with a maximum capacity of 1,600,000 ten-digit words. Available in increments of 160,000 words, the auxiliary storage capacity may be expanded as needed. The first unit contains all control circuitry for operation of itself and up to nine additional 160,000-word units. Conversion of earlier computer systems, to permit use of auxiliary storage facilities, will be a simple process.

The command list for systems assembled around the 203 computer is unusually flexible for a machine of its size. Included are decision and comparison commands, several of which use a special register to modify the address associated with an instruction. The technique greatly simplifies coding, by allowing a short list of operations to be performed on a long succession of numbers.

The design of the 203 computer permits choice of several input methods. Numbers and commands may be read in by means of standard punched-card equipment or by a specially designed photoelectric reader, which can insert 450 decimal characters per second into the computer's memory from previously punched paper tape. Manual insertion provision is provided in all computers. The output of the machine is similarly flexible. Data may be read out into standard punched cards, tabulated in alpha-numeric form, or punched into paper tape.

Conservative electrical design and standard components operating at well under their rated limits ensure reliable operation for long periods. In addition, maintenance is facilitated by built-in test circuits and



Spindle-cum-bearings

Here is a useful unit which is incorporated in a great many motor cars and tractors: it is the spindle and bearing assembly for the fan and water pump.

Its advantages are self-evident; it is very compact and the inner race is kept down in size, an advantage with a fast-running spindle. The provision of the two outer races in one piece simplifies the housing and eliminates the risk of misalignment in bearing seatings bored from opposite ends.

We show some of the variations of this bearing which we make, because we feel that as a type it could be adapted—not necessarily in the same sizes—to a great many new uses.

To those interested, the collaboration of our engineers is freely available.

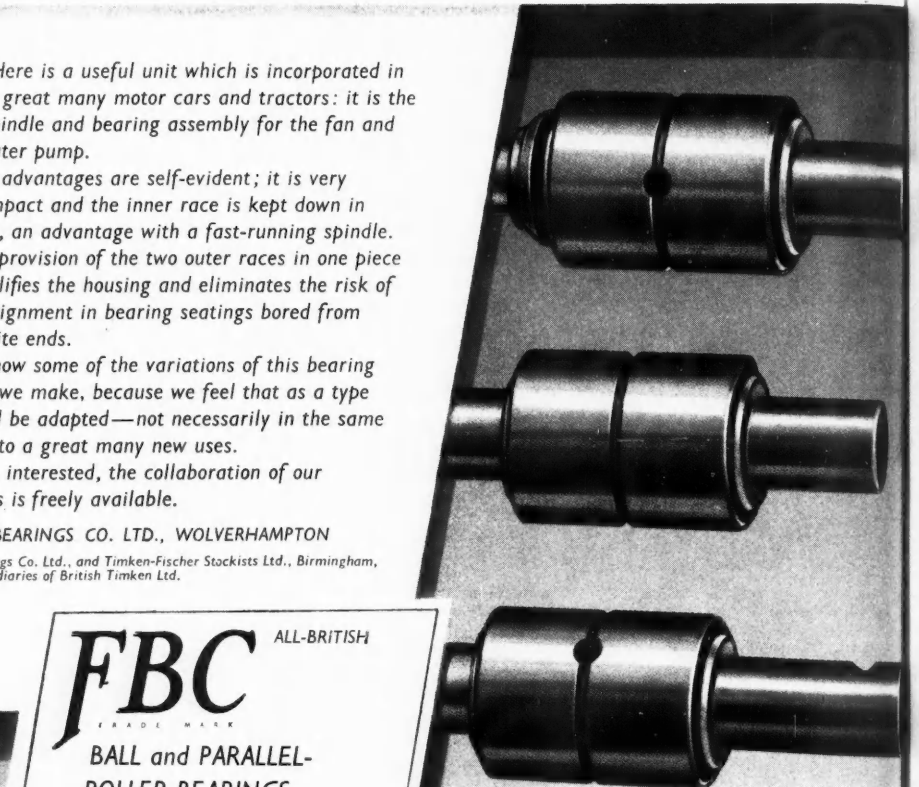
FISCHER BEARINGS CO. LTD., WOLVERHAMPTON

Fischer Bearings Co. Ltd., and Timken-Fischer Stockists Ltd., Birmingham, are both subsidiaries of British Timken Ltd.

FBC TRADE MARK ALL-BRITISH

BALL and PARALLEL-ROLLER BEARINGS

F.B.C. :: FISCHER



SCALE: SLIGHTLY REDUCED

controls, and by standardised, quickly replaceable plug-in units. A maintenance panel, which shows at a glance the contents of all registers and critical toggles, makes it possible to follow any problem step by step. Furthermore, the machine can be operated by personnel with only limited technical skill, after problem analysis and preparation by trained mathematicians.

AUTOMATIC BENDING MACHINE

A series of new automatic bending machines has been developed by Pines Engineering Company, of Aurora, Illinois, by means of which production problems of cold-forming parts from round, square, rectangular, extruded, or hollow stock to an even radius, or to different angles, can be correctly and easily executed.

These machines are made from heavy steel plate, arc welded and heavily reinforced for rigidity. The entire base serves as a reservoir for hydraulic oil, and all piping for the hydraulic system is located directly above the oil reservoir. The hydraulic pump is mounted inside the base and the pump motor is mounted outside the base, where it is easily accessible.

Operation is by push-button controls, the main control unit being a portable switch equipped with start, stop, and reverse buttons. The machine is started by the momentary contact of the start button, after which the clamp, followed by the pressure die, closes, the bending arm rotates to a predetermined angle, the mandrel is extracted, and finally the clamp and the pressure die open. Pressing the reverse button brings the bending arm back to the starting position, after which the mandrel automatically advances to working position. The third button is used to stop the machine in an emergency at any point in the bending cycle. It also aids in the original set-up by permitting inching of the clamps or the movement of the bending arm. An automatic cycle switch, when closed, causes the machine to go through the entire cycle by using the start button only.

Extremely high pressures are used for clamping the tubing on the machine, so as to avoid slippage. This is accomplished through a hydraulic cylinder which actuates a toggle mechanism for closing the clamp. The pressure is adjustable to any amount desired by means of a hand screw.

In the bending of light-wall tubing to an extremely short radius, the concentricity of the bending form is extremely important. All these machines are equipped with a centering ring, which fits into the bending arm and centres the bending form, to ensure that the bending groove runs true with the axis of the spindle. The spindle of the bending arm is pressed into a hole drilled in the steel casting, after which the spindle is welded into place and machined. This prevents any lost motion developing in operation and is an important factor in maintaining accurate angle of bend. Adjustable, tapered roller bearings eliminate any lost motion in the bending arm.

The sprocket driving the spindle is fitted with a tapered bore, mounted on the tapered spindle, and locked by a large key. This construction permits ease of assembly or dismantling, and also ensures that the key will not work loose in service.

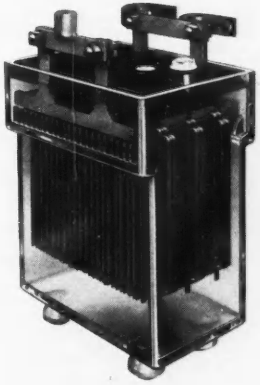
The illustration shows an eight-foot length of steel tubing, 3 in. square, with a $\frac{1}{4}$ in. wall, being compound-bent to close tolerances.

SEALED-IN STATIONARY CELL

The range of sealed-in stationary cells produced by Chloride Batteries Ltd., of Clifton Junction, Swinton, Manchester, for emergency lighting and power, switch closing, and similar duties in industry, has been increased by the addition of what is perhaps the largest standard sealed-in cell now available. Designated the Chloride GCG10E, the new cell has a capacity of 450 ampere-hours at the 10-hour rate of discharge down to a final voltage of 1·85. It is eminently suitable for operation on all types of circuit, whether "floating," trickle-charge, or straight charge and discharge.

Assembled in robust glass boxes of ample section, with moulded shoulders to support the plates, and integrally moulded feet, the cells are designed for mounting on single-tier stands, with their plate edges adjacent to each other. Intercell connections are, therefore, short and the voltage drop under heavy discharge conditions is consequently reduced. The moulded ebonite cell lids, each provided with an internally screwed vent hole to accommodate a baffle-type porcelain vent plug, are sealed to the boxes by a special bituminous compound.

Ten Plante positive plates and eleven box-type negatives, burned to their respective group bars, comprise the elements of the new cell. Each plate is provided with two hanging lugs, which rest on the shoulders of the glass box, and lead springs are fitted at the end of the elements to prevent the plates from splaying.



Flat sheets of plastic material ("Porvic"), each mounted in three slotted dowels of polystyrene, provide the necessary separation between plates of opposite polarity. These separators, held in position by moulded snugs at the top of the dowels, which rest on the positives, form a continuous diaphragm between the plates, thereby avoiding any possibility of internal short circuits. More than 80% porous, yet an excellent insulator, "Porvic" remains unaffected by the electrolyte, even

We don't ask you to take to the Bush...

. . . we want you to take to the GLACIER STANDARD BUSH, and the whole commonsense idea of Standard Sizes.

Suppose you're stubborn . . . Suppose you ignore our advice, demand a bush specially produced, in meagre quantities, to some bastard size of your own which entails special drawings, patterns, toolings and so on . . . Very well ! For the sake, perhaps, of a trifling difference in one dimension (and your own naughty pride) you pay more and wait longer—and kick yourself thereafter.

Suppose you follow our advice . . . Why, then you discover that our Standard Range covers 191 variations in perfect series, graduating in length, nominal bore, and housing size. You take your pick from five grooving designs. You order from stock for immediate delivery, finished and ready in Glacier lead bronze, with an allowance in the bore for final sizing. You waste no time and you pay less.

Whether it's bronze bushes, wrapped bushes

or bronze bars, that's the logic behind . . .

GLACIER Standard Sizes

REGD. TRADE MARK

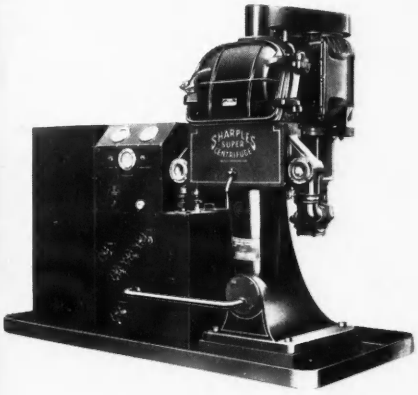
THE GLACIER METAL COMPANY LIMITED, ALPERTON, WEMBLEY, MIDDLESEX

under the most extreme conditions of service. Intercell connections consist of lead-plated copper straps fixed to the two positive and two negative terminal risers of each cell by lead-covered bolts and nuts.

The recommended normal charging rate is 62 A, reducing to 31 A towards the end. The overall dimensions of the cell are 10 in. × 14 $\frac{5}{16}$ in. × 19$\frac{1}{2}$ in. high, and the weight is 224 lb, complete with approximately 4 gallons of acid.

TURBINE LUBRICATING OIL PURIFIER

To meet the requirements of power stations for a turbine lubricating oil purifier, designed specifically for that purpose, and incorporating an indirect type oil heater, Sharples Centrifuges Limited of Woodchester, Stroud, Glos., have developed two new ranges of installations. These are both based on the Sharples tubular bowl super-centrifuge, and the general layout of the units has been designed to conform with modern standards of power-station practice as regards appearance and ease of cleaning.



The new Sharples Series " S " turbine lubricating oil purifier is the standard model designed for power-station use, where economy in first cost is considered paramount. The heater controls and motor starter are panel-mounted, but the pressure gauge, oil thermometer, and valves are mounted directly on the pipe work. It is considered that this model is suited to the majority of applications.

The new Sharples Series " D " turbine lubricating oil purifier (illustrated) is designed for mounting on the turbine floor in circumstances where a particularly neat appearance is the first consideration. In this model, all controls and instruments are grouped together on a flush-fitted control panel, giving an overall appearance in keeping with the most modern turbine-room layout. The unit is especially simple to operate and to maintain in a high degree of cleanliness.

The purifier incorporates a feed pump, or discharge pump, depending on whether feed to the purifier or return from the purifier is by gravity. Where the situation demands it, both feed and delivery pumps can be incorporated. The pumps are of the gear type and are driven directly off the centrifuge motor through a speed reducer mounted on the centrifuge frame. The pipe connections can be varied to suit particular operating requirements, and provision is made whereby the indirect oil heater can be by-passed at will without stopping the centrifuge, if it is desired to take the heater out of commission for inspection or cleaning.

The heater itself is of the indirect, electrically heated type, and the elements are so placed as to give the maximum thermal circulation in the water bath, and thus obtain a high overall heat-transfer coefficient. Circulation of the oil and water in the heater is arranged to be counter-current, in order to give the maximum temperature potential for heat transfer. A water-level sight glass is incorporated to facilitate periodical topping-up of the water bath. The water bath of the heater is of the " no-flow " type, and does not require a constant flow of water through it. This is advantageous, since it allows the bath to be fil'ed with condensate where possible, with the consequent elimination of scaling on the heater tubes, thus maintaining a high heater efficiency and eliminating the need for periodic de-scaling. In designing the heat-transfer coils of the heater, the oil flow rate in the tubes is maintained at a level sufficiently high to avoid sludge deposition, and the unit is so arranged that oil can be drained from the heater when not in use.

An oil temperature gauge and an oil pressure gauge are included in the circuit, as also is a pressure relief valve on the oil system, to guard against possible build-up of back pressure due to any unavoidable blockages of the line down stream.

ELEVATED ASSEMBLY LINE

A new " elevated railway " assembly production line, designed to speed output of anti-submarine aircraft for the U.S. Navy, has recently been developed by the Lockheed Aircraft Corporation, of Burbank, California.

By means of this system, a line of fuselage structures can be shifted from station to station along the assembly line in half an hour, as compared with three hours by previous methods.

The front and rear of each fuselage section are attached to lightweight frames, which roll on wheels along tracks raised several feet above the factory floor. Quick-disconnect electricity and compressed-air lines for rivet guns and other hand tools run adjacent to each track. Previously, each piece of fuselage was mounted on a bulky dolly, which was rolled along the floor.

Besides saving 2$\frac{1}{2}$ hours each time the line advances, this new rail-and-carriage system speeds up manufacture by providing unlimited accessibility to the entire

"SPEEDICUT"

Speedy Delivery, Speedy Performance

F. B. T.

FIRTH BROWN TOOLS LTD.

SPEEDICUT WORKS, CARLISLE STREET EAST,
SHEFFIELD.

assembly; by making possible a step-saving system of nearby tool and parts supply; by making more floor space available; by simplifying utility service; and by enabling more people to work simultaneously on one structure.

AUTOMATIC WELDING BLOWPIPE

With the conventional blowpipe, the correct flame (neutral, oxidising, or carbonising) is obtained by the operator setting the recommended pressure readings on the outlet gauges of both oxygen and acetylene regulators and then manipulating the blowpipe valves.

During the progress of welding operations, it is frequently necessary, because of positioning or adjustment of the workpiece, to withdraw the blowpipe flame, possibly only for a minute or so, during which time valuable gases are needlessly burned; alternatively, gases are shut off and much time is lost in consequent blowpipe flame re-adjustment.

The B.I.G. "Automatic" welding blowpipe, manufactured by British Industrial Gases Limited, of London, S.W.1, is designed to eliminate such wastage of time and gases. The blowpipe retains all the characteristics of the well-known range of B.I.G. welding blowpipes and is operated in exactly the same manner, once the original flame adjustment has been made. The operator controls the supply of oxygen and dissolved acetylene simply by moving the thumb control backwards and forwards. A forward movement brings on the full welding flame, while a backward movement shuts it off, leaving only a tiny pilot light.

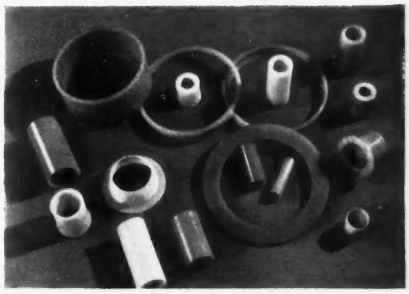
The "Automatic" blowpipe is available in two sizes, i.e., Model No. 16 for welding up to ¼ in. mild steel plate, and Model No. 17 for heavier sections, respectively.

POLYAMIDE PLASTIC

Manufactured by Algemene Kunstzidje Unie N.V. (A.K.U.), Arnhem, Holland, and distributed in the United Kingdom by Hercules Powder Company Limited, of London, W.1, "Akulon" is a type of polyamide (nylon) plastic with a large range of applications.

"Akulon" is a thermoplastic material which, on account of its high softening point, can withstand much higher temperatures than the usual thermoplastic materials. Softening points of various grades range from 200 to 220° C, the following grades being currently available: "Akulon" M2 and K2, which are the more rigid forms, and "Akulon" M10 and K10, the more flexible forms. The "M" grades are especially suitable for extrusion, and are superior in terms of wear resistance and toughness. The "K" grades are particularly suitable for injection moulding.

Outstanding advantages of this material include low specific weight; high corrosion resistance; low coefficient of friction; high wear resistance; resistance to low temperatures; ease of processing and moulding; noiseless operation; extreme toughness; and non-inflammability.



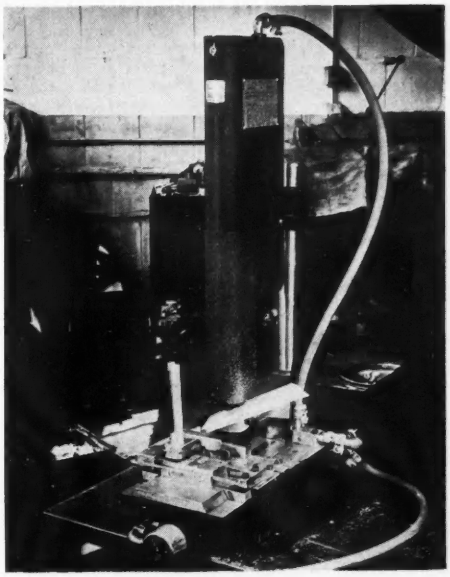
Besides its applications in the field of medical and hospital equipment, it has many others in the electrical, textile, and transport industries. For instance, it is an excellent extrusion coating for wires and cables, both as a primary insulation and a protective sheath. Gears made of "Akulon" are virtually noiseless, are of great durability, usually do not require lubrication, and can be made more economically than metal gears.

Other applications include building, furniture, and household appliances; gears, bearings, and other components of business machines, etc.; and bushes for shackle and king pins in trucks and other vehicles, generators, conveyors, pulley blocks, etc. In this connection, a selection of "Akulon" bushings, as used in automobiles, is illustrated.

AIR HAMMER

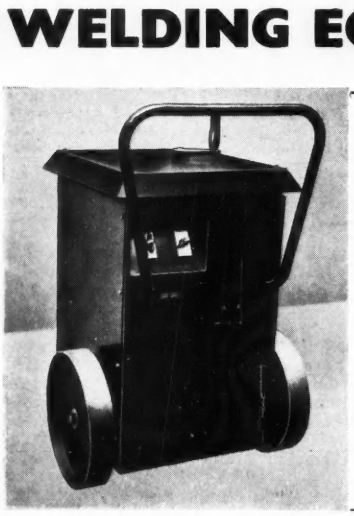
A new air-powered unit, known as the "Impact Hammer," has recently been developed by the Mead Specialities Company, of Chicago, Illinois. This small machine, weighing only 27 lb, is capable of performing a wide variety of operations, which hitherto have required much larger and more expensive machines.

There is no specific limit to the size of the sheet or number of holes which can be pierced with the new tool in one operation. With a suitable table, all four sides of a sheet can be pierced at one time. Where smaller work is to be pierced, several groups of these hammers can be mounted on one large table, each group



SOME EXAMPLES FROM THE COMPREHENSIVE RANGE OF

WELDING EQUIPMENT *by* PHILIPS

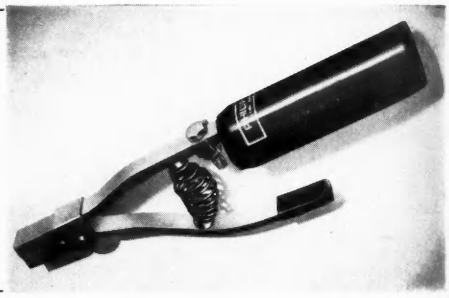


PHILIPS TYPE ES 3566
350 AMP. AIR COOLED
WELDING TRANSFORMER

A fully portable A.C. Welding Plant for medium and heavy fabrication. The transformer is suitable for connection to single phase or across 2 phases of a 3-phase 50 cycle supply. It is housed in a robust sheet steel cabinet — a built-in fan guarantees adequate cooling under all conditions.
Output : 60 — 350 Amps. Current continuously variable.
Arc Voltage : 24 — 34.5 Volt.
O/C Voltage : 75 — 80 Volt.
Primary Tappings : 190, 200, 220, 250, 380, 400, 440 and 500 Volts.
Total Weight : 3¼ cwt.

PHILIPS TYPE ES 1426 300 AMP.
ARC WELDING ELECTRODE HOLDER

Manufactured from high grade materials by the most modern factory methods employing arc and resistance welding, and High Frequency Heating. The resultant product is of excellent quality and finish and whilst being light in weight (20½-ozs.) its robust construction ensures a trouble-free life.
The Philips ES 1426 Electrode Holder is suitable for electrodes from 14 to 4 s.w.g. and operates without overheating over exceptionally long periods of continuous welding.



PHILIPS TYPE 1381/1
FULLY PORTABLE
WELDING TRANSFORMER

A fully portable A.C. Welding Plant for medium fabrications, sheet-metal welding, maintenance work and garage and agricultural repairs. Low initial outlay and low running costs are special features of this unit. Input links easily adjusted to permit connections to different supply voltages — 200, 225, 400, 440 volts; single phase 50 cycles, or across 2 phases of a three-phase system.
The welding current control is continuous over the entire range of 15 to 200 amps. Two current ranges are available :—
Low range — 15 to 100 amps. O/C voltage 80/100 volts.
High range — 30 to 200 amps. O/C voltage 40/50 volts.
Approximate dimensions — 1 ft. 6½ in. x 1 ft. 5 in. x 1 ft. 11½ in.
Approximate weight — 200 lb.

For full details of complete range, write for Philips Arc Welding Catalogue PD.3515

PHILIPS ELECTRICAL LIMITED

INDUSTRIAL GROUP, CENTURY HOUSE, SHAFTESBURY AVENUE, LONDON, W.C.2

INDUSTRIAL X-RAY EQUIPMENT · ELECTRONIC APPARATUS · LAMPS AND LIGHTING EQUIPMENT · ARC AND RESISTANCE WELDING PLANT AND ELECTRODES · MAGNETIC FILTERS · BATTERY CHARGERS AND RECTIFIERS · H.F. HEATING GENERATORS · RADIO AND TELEVISION RECEIVERS (W2386

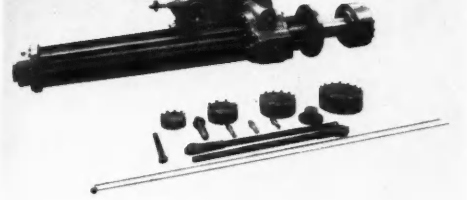
being independently controlled by its operator. Thus, each operation may follow its own cycle and need not wait for the slowest of the group.

The machine can be operated in any position, thus making it adaptable to piercing large sheet-metal items after forming. The capacity at 100 psi is a $\frac{3}{8}$ in. hole in 0·065 in. cold rolled steel. The ram delivers a blow equivalent to approximately 4500 lb pressure. With suitable attachments, the hammer is also suitable for upsetting rivets, blanking-out soft materials with knife dies, light coining and forging operations, and stamping letters and numbers on plastics and other synthetic compositions, brass, bronze, aluminium, and steel.

The impact can be readily adjusted from the maximum of approximately 4500 lb to a minimum of only a few ounces. The cycle of the ram is automatic, returning after each blow to the " cocked " position, ready for the next stroke. Several blows per second can be struck. The mechanism of the new tool is extremely simple, there being only two moving parts besides the ram itself. Air consumption at full stroke amounts to only 5 cubic inches per cycle.

UNDERPRESSURE PIPELINE DRILLING MACHINE

Whilst for many years underpressure drilling and tapping machines have been available in Great Britain for ordinary service work on gas or water mains, the provision of machines for dealing with the much higher pressures experienced in the oil industry has until recently been the prerogative of American manufacturers.



During the past five years, however, Messrs. E. Pass & Co., Ltd., of Denton, Lancs., have produced a number of machines, which have already been supplied to several of the leading oil companies. A new Pass machine, the Number 3 Enclosed-Gear Underpressure Drilling Machine, for cutting holes of from 8 to 20 in. in diameter in steel pipe lines (hot tap), has been recently completed and supplied to the order of the Kuwait Oil Co., for their Middle-East refinery. The machine has a maximum traverse of 72 in., to enable tappings to be made through 20-in. oil valves and welded flanged necks. It is operated by a 6-hp air motor and all gears are completely enclosed. Clutches are provided to enable automatic feed to the cutter to be changed over instantly to quick traverse. This is an essential feature when feeding the cutter to the pipe. Centre drills and pilots fitted with plungers ensure that the trepanned piece (fish) is retrieved. It is understood that this is the largest machine of its kind yet made.

The principle of operation is a conventional one, by means of which a section of the pipe is cut out by the drilling mechanism of the machine, and then withdrawn through a full-way valve, the closing of the valve permitting the machine to be removed from the valve flange without appreciable loss of oil. The amount of feed or traverse on the machine may be checked by means of the " dipstick " provided. The illustration shows the new machine, with its range of accessories, and affords an idea of its unusual length of traverse.

It will be appreciated that in the case of an enclosed machine, danger to the operator could result, if a shaft seal failed and the casing of the machine became pressurised at 1500 psi. For these high pressures, Messrs. Pass & Co., Ltd., offer an open-type machine which presents no such hazard, and any escape of oil or vapour at high pressure through the shaft seal occasions no danger to the operator. It is suitable for use on pressures up to 1500 psi by either hand or power operation. Both patterns of machine can be supplied with either flanged or screwed adaptors.

SINGLE-STAGE MAGNETIC AMPLIFIER

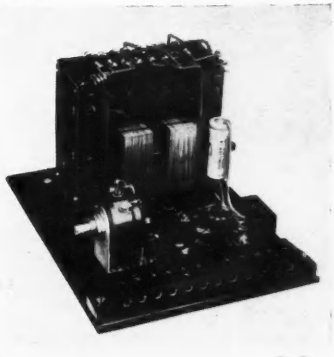
In view of the considerable interest now shown in the application of magnetic amplifiers, a unit specially intended for the instruction of students and also for laboratories where a magnetic amplifier application is under consideration, has been developed by Electro Methods Limited, of Stevenage, Herts.

The amplifier is designed in such a way that its basic principles of working can be easily investigated. All the important measuring points are easily accessible, and the circuit can be traced by following the colour-coded connections. Full working instructions are supplied.

The unit consists of a transformer-like structure, comprising two magnetic cores of high-permeability nickel alloy, so designed that a close approximation to a toroid is achieved. Each core carries two a.c. windings in series, the windings being connected in such a way that the relative polarity of the fluxes in the two cores is opposite. The two cores are embraced by common windings, referred to as d.c. windings. As these windings embrace the two cores, in which the polarity and magnitude of fluxes are exactly opposite, there are no voltages of fundamental frequency induced into them.

The magnetic amplifier is provided with positive feed-back, where the ampere turns are 100% with an additional 5%, which may be connected additively or subtractively, as desired, thus giving 95% to 105% feed-back. A smooth control of self-excitation may be obtained between these limits by connecting a variable shunting resistor in parallel with the 5% winding; a larger control of feed-back ampere turns may be obtained by connecting the shunt across the 100% winding. The bias may be varied by adjustment of the bias potentiometer, the current being provided by a small rectifier connected across the supply. A suitable condenser is connected across the bias rectifier, its purpose being to prevent rectification of the induced harmonic currents circulating in the bias winding.

The supply voltage is 20 V at 50 cps; the recommended load is not less than 30 ohms; the output power is 2·7 watts in 30-ohm load; and the power amplification is 40,000, with 100% self-excitation in 30-ohm load.



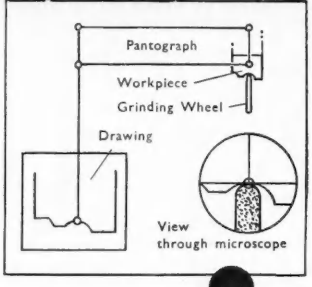
Wickman

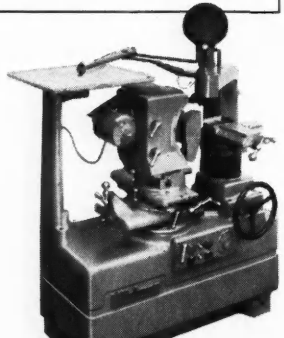
Optical

PROFILE GRINDING MACHINES

increase output in the up-to-date toolroom

A fifty-to-one drawing of the desired profile is mounted on the drawing table of the machine, and is used in conjunction with the pantograph system. The pantograph imparts a fifty-to-one reduction to its final arm in which is incorporated the projection unit.
Work is focussed under the microscope, and the tracing point of the pantograph moved along the drawn profile. The grinding wheel is fed manually into the work and the exact progress of grinding can be followed in the field of the projection screen or microscope.



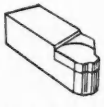


These machines are currently used in the toolrooms of a host of important aircraft, automobile, watchmaking and general engineering organisations for the production of profile gauges, form tools, press tools and many other highly precise aids to production.

Operators and managements in these works fully appreciate the value of the Wickman Optical Profile Grinding Machine—"The most helpful piece of equipment we've got," says one—and another, "We could not produce our type of work without it." We would like you to meet some of these users, we think they would convince you. Why not let us take you round, or send you fuller information.

CIRCULAR FORM TOOL
Grinding time 1½ hours
Accuracy ... ·001"

DIE GAUGE for Stator Blade
Gauge Steel
Stock removal ·015"
Grinding time 2½ hours
Accuracy ... ·0003"



FLAT FORM TOOL
Tungsten Carbide Tip
From unshaped tip
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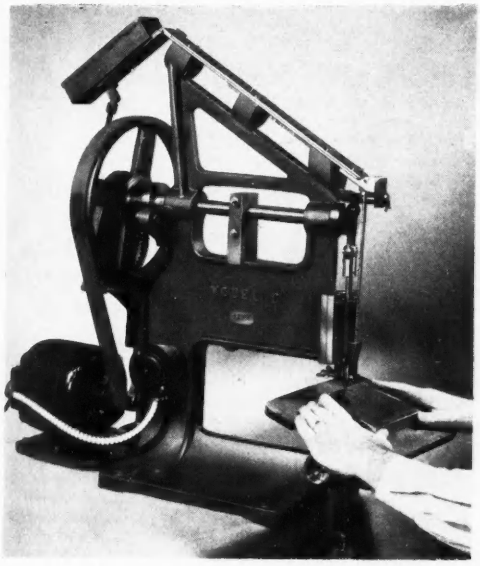
PRECISION PIN-DRIVING MACHINE

A new, improved Milliken precision nailer, which quickly and accurately drives nails, pins, and rivets into wood, plastic, metals, etc., is announced by Press Wireless Laboratories, Inc., of West Newton, Massachusetts.

Parts to be joined are held on the work-table under the nail jaw. Pressure on a foot treadle automatically drives the pin through the parts to be joined at the exact spot desired. The machine does not strike a blow; rather, it carries a sustained driving action off the flywheel. Consequently, various "difficult" materials, such as plastics, masonite, hard woods, and thin strips of metal can be nailed with little danger of splitting or cracking.

This improved nailer handles a variety of nails, pins, and rivets, ranging in size from $\frac{3}{16}$ to $1\frac{1}{4}$ in., and its use often eliminates any need for pre-punching or drilling. Five standard models are available, with throat depths ranging from 6 to $10\frac{1}{2}$ in.

The addition of a new secondary separator ensures that each nail feeds out of the jaw head in the correct position for driving into the work. New improvements also provide positive feed of drive screws and larger-size pins. A new non-skid, diamond-tooth work-table enables the work to be held firmly in position for nailing and pinning at any angle. By raising or lowering the table, nails may be driven flush, partially driven, or countersunk.



DUAL-CURRENT WELDING RECTIFIER

A new dual-current rectifier, the Philips Type 1308/1, designed to give an output of 40-240 A a.c. or 10-80 A d.c., has been announced by Philips Electrical Limited, of London, W.C.2.

In both the a.c. and d.c. ranges, the output is infinitely variable, and a calibrated scale is fitted, to indicate the welding current on either of the two ranges. The type of current is selected by means of a change-over switch. When direct current is required, the transformer output is fed to two rectifier valves, which are protected from premature loading by a time-delay valve and from excessive current input by a microswitch device, operated directly from the shunt mechanism.

The use of valve-rectified d.c. ensures that the welding current is smooth and free from "flickering." As there is no mechanical inertia and the electrical inertia of the set is low, there is a very rapid response, and arc recovery time is extremely short. Oscillograms show that barely 0·002 sec is required for recovery. The rectifier is suitable for connection to three-phase 380-440 V, 50-cps supply, but it can also be supplied for two-phase systems, 200-220 V, 50 cps, if desired.

The machine is contained in a well ventilated, stoutly constructed, drip-proof case of neat design. The valves are fully spring-mounted for arduous service. The approximate overall dimensions are $22\frac{1}{2}$ in. × 24 in. × 34 in. high, and the approximate weight is 385 lb.

MASS PRODUCTION OF TRANSISTORS

The Philco International Corporation, of Philadelphia, Pennsylvania, is reported to have developed a new germanium processing method which promises to make possible in the near future the mass production of a new type of transistor, capable of amplifying the weakest electrical signal to one of several watts.

A new unit has been evolved, operating with such an economy of power consumption that for the first time a portable military communications receiver working on very-high-frequency channels can be powered solely by two flashlight cells, and an appropriate receiver made to fit into a space no larger than that occupied by a packet of twenty cigarettes. Such developments bring into the realms of probability television and radio sets operable on fractional power consumption, and in the case of the latter, sets, equivalent to present standard equipment, housed in virtually pocket form, at prices well below those at present prevailing.

The new "surface barrier" transistor, as it is described, has operating characteristics which make possible its use at frequencies 10 to 100 times as high as those obtainable with alloy junction transistors. Behind its development lies a new method of processing germanium which overcomes previous difficulties of mass-producing transistors economically.

It is believed that the size of this transistor is not more than three or four sixteenths of an inch in diameter, with a capacity for amplification equivalent to that of an electron tube forty or fifty times the size, and that the power required to operate the transistor itself amounts to only a tiny fraction of a watt.

It is stated that marketing of transistor sets in Great Britain is unlikely at the present time.

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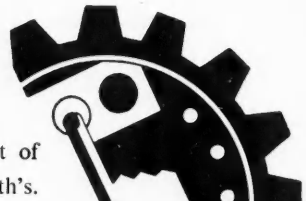

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CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns, are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

ELECTRONICS

The Electronic Determination of Weight.

By V. C. KENNEDY. (From *Mechanical Engineering, U.S.A.*, Vol. 76, No. 2, February 1954, pp. 159-165, 12 illustrations.)

FUNDAMENTALLY, a system for the electronic determination of weight comprises three basic elements, i.e., the load cells, the servo-system, and the data-presentation device. During operation, the weight to be measured is placed on the load cells. These cells, which consist of small electrical units sensitive to mechanical force, thereupon produce an output voltage proportional to the applied weight. This proportional voltage is fed into the servo-system, which interprets the magnitude of the voltage by automatically adjusting a balancing potentiometer to an equivalent position. At the same time as the servo-system positions the potentiometer, it also positions the data-presentation device (digit wheels in a printer, pointer of a dial, pen of a strip chart, etc.) to a corresponding position.

Although the components and techniques of electronic weighing have already undergone considerable advancement and are now being used successfully in numerous installations, electronic weighing as a whole may still be regarded as in its infancy. For example, the load cell has, as one of its many useful characteristics, the quality of being able to convert a weight force into a proportional voltage in a fraction of a second. This rapid response should pave the way to various high-speed motion weight installations. In this connection, electronic scales of such a type, capable of detecting the weights of vehicles travelling at speeds of more than 60 mph, are envisioned, and, indeed, may already be under test.

The fact that the load cell is relatively very small in size also has yet to be exploited fully. The possibility of incorporating load cells directly into the lifting apparatus of a fork-lift truck and installing a recorder on the dashboard immediately presents itself.

Whether such scales will be evolved in the near future will depend on several factors. An important aspect to be considered in this respect is the fact that electronic-scale manufacturers do not stand alone in their efforts to develop better components and techniques. Actually, such equipment, inherent in the electronic-weighing field, and particularly servo-mechanisms, are also being used extensively in a great many other fields. Thus, the chances are that forthcoming improvements in this type of equipment will be effected at an increased rate, and these improvements will lead to rapid advances in the field of electronic weighing, as well as in others.

FLOW OF FLUIDS

Component Losses in Kaplan Turbines and the Prediction of Efficiency from Model Tests.

By S. P. HUTTON. (From an advance copy of a paper submitted to *The Institution of Mechanical Engineers, London*, February 1954, 12 pages, 8 illustrations.)

DURING the past thirty years, there have been considerable developments in the use of Kaplan turbines for hydro-electric schemes, the cheapest and most economical use for this type being in low-head river installations. In such cases, the turbines are arranged with a short length of intake, drawing water from upstream of a weir and discharging through a draft-tube to the downstream side of the weir. Because of the shortness and shape of the water passages in many of these units, it is difficult to measure the flow accurately in the field, so that the full-scale efficiency cannot be checked with sufficient precision. The difficulty is often increased by the very large size of the turbine and the correspondingly elaborate measuring gear required.

In lieu of field tests, some buyers nowadays place contracts on the basis of properly executed model tests and the use of some stipulated scale formula to give the full-scale performace. This naturally makes it very important that model tests should be made as accurately as possible and also that the most reliable scale formula should be used. In the U.S.A., the "Moody (2)" formula is generally used, while on the Continent that of Ackeret is preferred. From experience of related model and field tests, it is now apparent that full-scale efficiency values lie somewhere between those predicted by these two formulae, the "Moody (2)" formula tending to overestimate, and the Ackeret formula tending to underestimate, full-scale efficiency.

This paper has been written in an attempt to provide for Kaplan turbines an improved scale formula which has theoretical justification and which offers reasonable results in practice. At optimum efficiency it is suggested that about 70% of the losses are frictional, and are therefore affected by Reynolds number, instead of 50%, as in the original Ackeret formula. The actual proportion will depend on the design and operating conditions of the machine, but the need for dividing the losses into frictional and kinetic parts, and the method of calculating their proportions, are demonstrated. The theory also shows that, between 0·5 and 1·5 times the normal flow, the proportion of runner to total losses may decrease from 90 to 50%, and due allowance should be made for this when scaling up performance away from the optimum.

The value of the theory and the formula can be assessed only after comparison with reliable experimental data but, in the light of the limited evidence quoted in this paper, it seems worthy of further examination.

ILLUMINATING ENGINEERING

The Equivalent Circuit of a Gas Discharge Lamp.

By C. ZWIKKER. (From *Philips Technical Review, Holland*, Vol. 15, No. 6, December 1953, pp. 161-168, 10 illustrations.)

THE gas discharge lamp, insofar as its electrical behaviour is concerned, differs in many ways from other circuit elements, amongst others in the non-linearity of its current-voltage characteristic. The behaviour of such a lamp in a circuit is, therefore, often difficult to predict in detail. It is sometimes considered that the gas discharge lamp can be replaced, schematically, by a simple resistance but, as is shown in this article, this may lead to false conclusions.

After dealing with the properties of gas discharge lamps in general, the characteristic of such lamps is discussed. If such a lamp is connected to an a.c. source,

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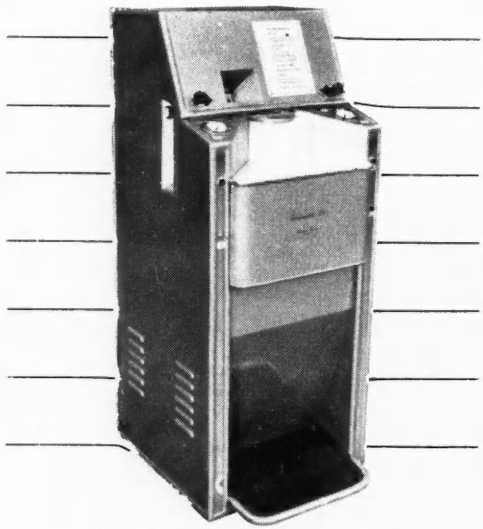

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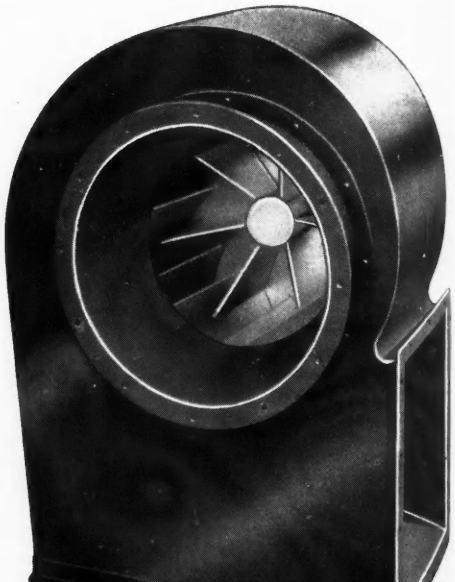

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the lamp voltage changes, to a first approximation, discontinuously from a positive to a negative value and *vice-versa*, and higher frequency components, i.e., harmonics, appear in the lamp current. The equivalent circuit of the lamp cannot, for various reasons, including that of the non-linearity of the characteristic, be composed only of resistances and other linear circuit elements; it can be represented only by a series connection of a.c. generators, with frequencies ω (mains frequency), 3ω, 5ω, etc. Employing this equivalent circuit, the fundamental component and the third harmonic of the lamp current are calculated to a first approximation. It is found that a gas discharge lamp generates a third harmonic of the order of 6-8% of the fundamental component. The amount of this passing into the mains depends further on the circuit in which the lamp is employed.

Finally, the current through the lamp is analysed to a second approximation, from which it is seen that, although, as indicated above, replacing schematically a gas discharge lamp by a simple resistance may easily lead to erroneous conclusions, it is possible to employ a "substitute" for the equivalent circuit, consisting of a series combination of a resistor and a small self-inductance. This arrangement can be useful in practice for testing purposes. For more exact calculations, however, it is necessary to employ a more comprehensive circuit which reproduces exactly the behaviour of the lamp.

IRON AND STEEL

The Diffusion of Sulphur in Molten CaO-SiO_2-Al_2O_3 Slag.

By T. SAITÔ and Y. KAWAI. (From *The Science Reports of the Research Institutes, Tôhoku University, Japan*, Series *A*, Vol. 5, No. 5, 1953, pp. 460-468, 6 illustrations.)

ACCORDING to recent studies, the speed of desulphurisation by molten slag is reported to be rather slow. The mechanism of desulphurisation may be analysed in the three following steps :—Diffusion of sulphur in the iron melt; transfer of sulphur at the interface between iron melt and molten slag; and diffusion of sulphur in the molten slag.

The speed of diffusion of sulphur in molten slag is slow compared with that in molten iron, so that diffusion in molten slag appears to be an important factor in determining the net rate of the reaction of desulphurising the iron melt. To measure such a low speed of diffusion, it is necessary either to carry out a very long run or to make an accurate determination of the concentration gradient of sulphur in the vicinity of the interface by means of some special method. The diffusion coefficient has already been measured by other investigators, but the method used gave only an approximate value, and it was impossible to measure its changes, owing to variations in the temperature and the composition of slag.

As the first step in the study of the kinetics of desulphurisation of iron by slag, the authors of this paper have determined the rate of diffusion of sulphur in molten CaO-SiO_2-Al_2O_3 slag by the use of radioactive sulphur S^{35}. Iron sulphide powder, made from barium sulphide containing S^{35}, was mixed with powdered CaO-SiO_2-Al_2O_3 slag and, after melting, this radioactive sample was poured into a graphite tube, which was coupled with a graphite crucible containing a non-radioactive sample of nearly the same composition as the radioactive sample. After heating in a high-frequency induction furnace in a nitrogen atmosphere for a definite period, and then cooling in the furnace, thin slices were successively cut from the top of the slag column, and the radioactive intensity of the polished surfaces of the remainder was measured by means of a Geiger counter. From these measurements, the diffusion coefficient of sulphur in a molten basic slag was determined.

The results confirmed that the rate of diffusion of sulphur in molten slags is considerably less than it is in molten iron. The diffusion coefficients in a basic slag were found to be $0{\cdot}90 \times 10^{-6}$ cm²/sec at 1445° C, $1{\cdot}5 \times 10^{-6}$ cm²/sec at 1515° C, and $2{\cdot}6 \times 10^{-6}$ cm²/sec at 1580° C. An expression for variation of diffusion coefficient with temperature was derived, and showed that a rise in temperature of 100° C will approximately double the value of the diffusion coefficient.

In an acid slag, the value of the diffusion coefficient was $0{\cdot}8 \times 10^{-6}$ cm²/sec at 1440° C, but, owing to the generation of carbon monoxide, with consequent agitation of the slag, the diffusion coefficient could not be measured at higher temperatures.

MARINE ENGINEERING

Correlation of Model and Ship Trials of a Shallow-Draught Rhine Vessel.

By W. P. A. VAN LAMMEREN and J. D. VAN MANEN. (From a paper presented at a meeting of the *North-East Coast Institution of Engineers and Shipbuilders, Newcastle-upon-Tyne*, February 26, 1954, pp. 279-328, 38 illustrations.)

IN order to judge accurately the resistance and propulsion qualities of a river vessel by means of a model test, it is necessary to make a study of the allowances required to bring trial-trip and service results into agreement with the results of the model test. The allowances on the model-test results of river vessels are different from those of sea-going vessels. On the one hand, there will be no resistance increase due to sea-way in the case of river vessels and, on the other hand, owing to the flow phenomena of the river, acceleration and deceleration forces will cause extra resistance. Tests with a single-screw, shallow-draught Rhine tanker have shown that it is impossible to determine the speed of the ship by direct measurements in a restricted depth of water on the river. The ship is constantly in accelerated or decelerated motion, as a result of the irregular flow phenomena of the river. This circumstance does not simplify the determination of the allowances necessary to bring the service results into satisfactory agreement with model-test results.

In this paper, a method is given of determining these allowances, taking as a starting point the results of model tests carried out at the Netherlands Ship Model Basin, Wageningen, Holland, and the rpm/power relation measured on the ship. In model tests, the influence of the width of the tank increases as the depth of water decreases. The fact, however, that the resistance curves for one depth of water and varying tank widths coincide, when plotted against the Boussinesq number $V_s/\sqrt{gR_h}$, where R_h is the hydraulic radius [metres], and V_s the speed of the ship [km/hr], provides a simple, though valuable, basis for the elimination of the wall effect in model tests.

METALLURGICAL ENGINEERING

Production of Oriented Single-Crystal Silicon Iron Sheet.

By C. G. DUNN. (From *Metal Progress, U.S.A.*, Vol. 64, No. 6, December, 1953, pp. 71-75, 6 illustrations.)

WITHIN the last decade, so-called grain-oriented silicon iron strip has become an important industrial product, by virtue of its magnetic properties, which approach those of a properly oriented single crystal. The marked improvement in magnetic properties of grain-oriented strip occurs when the path of the magnetic circuit coincides with the concentration of cube edge directions, as these directions in the crystal lattice are magnetically superior to other directions.

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A silicon iron sheet, consisting of an " oriented " single crystal, can be produced from a suitable polycrystalline sheet by recrystallising it through the growth of a single nucleus. However, not all polycrystalline sheet materials have the required crystal-growing characteristics. Also, the method of fabrication should be taken into account, as there is a relationship between preferred orientations required for crystal growth and the amount of hot or cold rolling and intermediate anneals.

In this article, three methods are described for producing suitable sheet or strip material from commercial silicon iron of the following composition: 3·25% Si, 0·025% C, 0·034% Mn, 0·010% P, 0·017% S, 0·067% Ni, 0·068% Cu, 0·012% Sn, and traces of Al and Cr. All three methods start with a plate or band, 0·10 in. in thickness, which has been hot rolled from silicon iron ingots.

The steps for producing a large oriented single crystal of recrystallised silicon iron, prepared by one of these three methods, may be summarised as follows :—

(1) One or more crystals are obtained in the end of a sheet (or strip) by placing it into the hot portion of a furnace with a high temperature gradient.

(2) The sheet is removed and one crystal is selected for the seed crystal. This crystal must be adjacent to the matrix.

(3) A transmission Laue pattern of the seed crystal is obtained.

(4) The orientation of the seed crystal is obtained from the Lauegram, and the axes and angles of rotation, to bring the crystal into the desired orientation, are determined with the aid of a Wulff net.

(5) The unwanted crystals are cut away, leaving the seed crystal connected to the strip by a narrow neck.

(6) The seed crystal is clamped in the crystal orienting apparatus, and is changed to the desired orientation with respect to the sheet, by bending the neck of the specimen while at red heat.

(7) The seed crystal in the new orientation is then made to grow and to replace the matrix of the entire sheet by passing the sheet slowly through the hot zone of a high-temperature-gradient furnace.

POWER-PLANT ENGINEERING

Pumped-Storage Hydro-Electric Plant.

(From *Power, U.S.A.*, Vol. 98, No. 1, January 1954, page 97, 1 illustration.)

ALTHOUGH pumped-storage hydro-electric plants are used extensively in Europe, only two have gone into operation in the U.S.A., while equipment is on order for only two more.

Now, however, it is reported that a giant pumped-storage scheme, with a total capacity of 400 MW and a pumping head of from 750 to 800 feet, is proposed for installation on Lake Erie. A reservoir is to be formed by a dam across each of the two ends of a valley in the Allegheny Mountains, at an altitude of over 1300 feet. When the reservoir is full, water level will be at an elevation of 1390 ft, the average depth being about 70 ft. The dams, which are six miles apart, are each about 100 ft in height. The valley will thus form a huge basin, which will become a reservoir of 400,000 acre-feet capacity, covering an area of about 11 square miles.

The pumping and power plant, to be located on the shore of Lake Erie, will be an outdoor type, and will consist of a series of stalls, one for each main power-generating and pumping unit. Plant capacity will be determined by the peak-load requirements of the system to which it connects. Units are to be of the reversible type, each consisting of a pump/turbine and a generator/motor, of about 100,000 hp capacity. For pumping, the generator/motor will operate as a motor, taking off-peak energy from the power system to drive the hydraulic unit as a pump to discharge water into the reservoir. During peak-load periods, the unit will reverse direction of rotation, the pump/turbine then becoming a prime mover, which will take water from the reservoir to drive the electric unit as a generator. Preliminary studies indicate an initial installation of five 80-MW units.

Each unit will connect to one dam of the reservoir by a penstock, about 4·5 miles in length by 10 ft in diameter. Water level in the reservoir will change from hour to hour, day to day, and season to season in periodic cycles, according to operating schedules. Normal variations will be from 5 to 10 ft daily, and about 20 ft per week, with a maximum of about 60 ft.

PRODUCTION RESEARCH

The Impact of Development and Research on Production and Design.

By L. H. LEEDHAM. (From a paper presented at a meeting of *The Institution of Mechanical Engineers, London*, February 19, 1954, 8 pages.)

PRODUCTION engineering in Great Britain is gradually assuming great importance as an independent subject, the techniques of which require concentrated study and research. To some extent, the time has passed when the engineering industry regarded production men as being somewhat " inferior," but there are still hundreds of concerns where only very inadequate production facilities exist, and where there is little appreciation of the need for better quality personnel. Such environments afford little inducement to the study of production techniques ; as a result, personnel is often found by promoting men from the operative level. Some very able men have, of course, so arisen, but their success is probably due more to an understanding of the problems of works personnel than to technical competence.

It is imperative to have well qualified and imaginative men directing manufacture. Production engineering in Great Britain must be raised from the solely " practical " level to which it has hitherto been relegated and be established on a higher plane.

This paper deals with some technical activities which are of particular importance in relation to production, but which are not always recognised as having a direct bearing thereon. Simplification of product, functional development, and production research provide means by which existing facilities may be made to yield greater output, i.e., to increase production efficiency. They also ensure that industry will in the future employ those processes which produce the maximum economic gain.

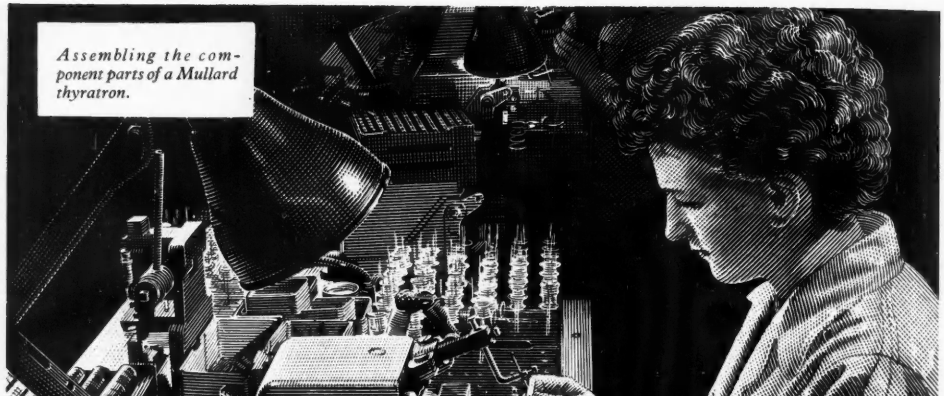
The attitude of the mechanical engineer to production techniques as a part of design also receives consideration, together with the desirability of infusing designers and draughtsmen with a greater interest in new methods. The responsibility of industry in affording training is also discussed. The lack of adequate support for production research is emphasised, while attention is drawn to the difficulties of small firms in deriving benefit from the results of research and development work on new processes.

RAILWAY ENGINEERING

The Measurement of Train Resistance.

By H. I. ANDREWS. (From a paper presented at a meeting of *The Institution of Locomotive Engineers, London*, February 10, 1954, 54 pages, 45 illustrations.)

IN any calculation of train motion, it is essential that the running resistance of the vehicles concerned should be known with reasonable accuracy. Such calculations are daily required in the working of a railway, and are now needed particularly in connection with economic



Assembling the component parts of a Mullard thyratron.

PROGRESS IN ELECTRONICS

THE utilisation factor of an electrically powered machine is often dependent upon the flexibility of its motor. Until quite recently all motors were controlled by conventional electro-mechanical equipment. To-day, however, an increasing number are controlled by an electronic valve known as a thyratron.

The thyratron is a device which can convert alternating current to direct current and, at the same time, can regulate the amount of current—and thus the amount of power — released to the motor.

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train timing. An increasing amount of information is now becoming available as to the performance and efficiency of various classes of locomotives, and it has therefore become necessary to make corresponding determinations of the resistance of modern types of passenger and goods vehicles on British Railways.

Investigations into the resistance of trains have, of course, been made for many years. However, the most extensive investigation was probably that of Schmidt, at the University of Illinois, between 1908 and 1934. A series of measurements of the resistance of twelve bogie coaches, both full and empty, was carried out by the German State Railways in 1931, while a similar series of tests on both passenger and goods vehicles was made by Clarke on the Indian State Railway in 1935. In none of these investigations, however, was it found possible to make any systematic determination of the separate effect of wind upon the train.

In this paper, the results of a series of tests and measurements of resistance of locomotives, passenger coaches, goods vans, etc. are detailed. The use of the mobile testing plant developed between 1936 and 1939 by the former L.M.S. Railway, together with the use of the fen lines of the Eastern Region and the statistical method of analysis adopted, has enabled the resistance of these vehicles, including the wind resistance, to be determined with a convenience and accuracy not hitherto possible. Separate determination of wind resistance is particularly important, as it permits estimation of the maximum resistance likely to be encountered in high winds.

The values of resistance now obtained are much lower than those given by Schmidt and Clarke, and probably indicate that the resistance of passenger trains in Great Britain is less than it is in the Middle Western States of America or in India. It is also interesting to note, in comparison with these and earlier results, that there appears to have been a progressive decline in passenger-train resistance over the last hundred years. Similarly, the resistance of goods vehicles, as measured by Schmidt and Clarke, are higher than those obtained in Great Britain, though consideration must here be given to the great differences in working conditions in the countries concerned.

One particularly interesting feature of these results is that all the values of air resistance measured are considerably lower than those generally forecast from wind-tunnel experiments. It has, however, been suggested that this is probably due to the difficulty of interpreting the scale effect of wind-tunnel experiments and possibly, to some extent, to the difficulty of reproducing the effect of the ground in a wind tunnel.

All the vehicles tested were selected more or less at random from types which will in future be standardised on British Railways, and which were in differing states of repair. Furthermore, the tests were carried out over lines with greatly differing subsoil, so that the results obtained may reasonably be regarded as typical of normal circumstances on British Railways.

VIBRATIONS

The Vibration of Rectangular Plates.

By G. B. WARBURTON. (From an advance copy of a paper submitted to *The Institution of Mechanical Engineers, London*, January 1954, 12 pages, 6 illustrations.)

IN this paper are considered the free transverse vibrations of rectangular plates, with all possible boundary conditions obtained by combining free, freely supported, and fixed edges. The Rayleigh method, assuming waveforms similar to those of beams, is used to derive a simple approximate frequency expression for all modes of vibration. The terms in this expression depend on the nodal pattern and the boundary conditions; they are tabulated for fifteen boundary conditions—all four edges free, freely supported, or fixed, and the twelve cases in which some of the edges have one condition and the rest another. The expression can also be used to obtain frequencies for a plate which has a combination of all three boundary conditions. The effect on frequency of an edge being supported and partially restrained is discussed.

For some boundary conditions, it is possible to compare derived frequencies with those obtained by various methods of accurate analysis and by experiment; except for a few cases, results from the approximate expression and accurate analysis agree closely.

For rectangular plates and for most boundary conditions and modes of square plates, the nodal pattern consists of lines approximately parallel to the sides of the plate. The exceptions are discussed and the gradual transition from these non-parallel patterns characteristic of a square plate to those of a rectangular plate is traced. The frequencies of extensional vibrations of rectangular plates are derived for two boundary conditions.

Throughout the paper, the plates are assumed to be isotropic, elastic, free from applied loads, and of uniform thickness, and the analysis is based on the ordinary theory of thin plates. Also, the thickness is assumed to be small in comparison with the wave-length.

WELDING

Inert-Tungsten Arc Welding of Stainless Steel Piping.

By F. J. PILIA. (From *The Welding Journal, U.S.A.*, Vol. 32, No. 12, December 1953, pp. 1167-1174, 36 illustrations.)

DURING the past several years, considerable progress has been made in eliminating backing rings from welded piping assemblies. This development has been made possible by refinements in inert-gas-shielded arc welding, using a tungsten electrode. It is now possible to produce a surface on the inside of a welded pipe joint, which is smooth and free from obstructions, notches, crevices, and traps for the material flowing through the pipe. Welds made in this manner do not require finishing, and are satisfactory for handling corrosive liquids, high-pressure and high-temperature steam, fluid metals, etc.

This paper describes a controllable technique for producing interior pipe surfaces of this type. At present, this technique is limited to fabrication of the type 300 series stainless steels, but techniques are being developed to weld carbon steel, chromium steel, and low-alloy steel piping. This technique makes it possible for a welding operator and a trained observer to determine the contour and condition of the penetration bead being formed on the inside of the pipe, by observing the weld puddle from the outside of the pipe.

The high degree of operator skill previously required to produce this type of joint has been significantly reduced. An operator of average skill can be trained to determine the proper corrective procedures required to produce a satisfactory interior surface in the pipe. The width of the penetration bead inside the pipe can be held to $\frac{1}{8}$ in. $\pm$ $\frac{1}{16}$ in., and the height can be held flush, $\pm$ $\frac{1}{32}$ in. The radius of the penetration bead can be controlled to $\frac{1}{2}$ in. Weld beads within these dimensions present a smooth interior surface, with the weld penetration bead blending into the adjacent surfaces of the pipe. It has been found in actual application that the use of this controlled technique makes it possible to maintain quality control of a welding operation which previously was dependent solely on the skill of the operator.

This technique takes advantage of the fact that a fluid weld puddle changes shape when certain conditions are present. The changes in contour of the weld puddle and the associated conditions of bead formation permit the operator to " read " the weld puddle.

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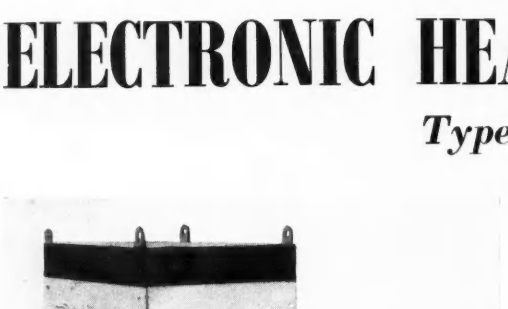

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NEWS OF THE MONTH

PERSONAL

Mr. M. E. Adams, O.B.E., M.I.C.E., has been appointed civil engineer-in-chief at the Admiralty, in succession to **Sir F. Arthur Whitaker, K.C.B., M.Eng., M.I.C.E.,** who retires on March 31st.

Mr. F. J. Aldridge has been appointed manager of the cable test and research department of Johnson & Phillips Ltd., Charlton, London, S.E.7.

Col. E. G. Angus, C.B.E., M.C., T.D., D.L., J.P., chairman and managing director of George Angus & Co., Ltd., Newcastle-upon-Tyne, has been elected chairman of the Northern Regional Council of the Federation of British Industries.

Mr. James Archdale, executive director of James Archdale & Co. Ltd., **Mr. Brian Davidson,** commercial director of the Bristol Aeroplane Co. Ltd., and **Mr. C. E. Wrangham, C.B.E.,** director of C. Tennant Sons & Co. Ltd., have been appointed to the Monopolies and Restrictive Practices Commission for a term of three years.

Mr. H. I. Arnold has been appointed sales director, and **Mr. A. E. Griffin** has been appointed general sales manager of Exactor Ltd., 108 Park Street, London, W.1.

Mr. E. E. Baldwin has been promoted to the position of works manager of the High Wycombe factory of Hoover Ltd. **Mr. J. C. Shapley,** who has organised the initial production of the Hoover Steam-or-Dry Iron at High Wycombe, is returning to the main Hoover factory at Perivale, Middlesex, in the capacity of chief production engineer. **Mr. E. Bennett** has been appointed production manager, and Mr. J. T. King, production engineer, at the Hoover factory at Cambuslang.

Following the transfer of **Mr. W. L. Beeby** to the Edison Swan Electric Co. Ltd., **Mr. C. H. Smith, A.M.I.Mech.E.,** has been appointed works engineer of Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester 17. **Mr. J. H. Phillips** has been appointed assistant works engineer.

Mr. P. Beynon has been appointed manager of the newly formed work study department of the Steel, Peech & Tozer Branch of The United Steel Companies Ltd. **Mr. E. Houghton** has succeeded Mr. Beynon as spring shop manager.

Mr. G. A. Black, Mr. W. Douglas, Mr. John Goodlet, Mr. W. Holloway, Jnr., and **Mr. R. G. Sewell** have been elected executive directors of Martin, Black & Co. (Wire Ropes) Ltd., Speedwell Works, Coatbridge, near Glasgow.

Mr. F. W. Bugless, M.I.P.E., works manager of Percival Aircraft Ltd., has been appointed works director.

Mr. A. C. Burdon, Mr. N. C. A. Spurgeon and **Mr. E. W. Swales** have been appointed deputy managing directors of the Automative Products Co. Ltd., Leamington Spa, and its associated companies, the Lockheed Hydraulic Brake Co. Ltd. and Borg & Beck Co. Ltd. **Mr. J. B. Emmott** has been appointed to act as an alternate director to any member of the Board. **Mr. E. Beaumont** has been appointed executive director (production), **Mr. S. M. Parker,** executive director (engineering), and **Mr. S. Westwood Smye,** executive director (purchasing), for the three associated companies.

Sir Charles Colston, C.B.E., M.C., D.C.M., chairman and managing director of Hoover Ltd., who has led the British Hoover organization in its growth and development from its beginning to its present position as world-wide manufacturing and trading organization with a staff of 12,000, factories in England, Scotland, Wales, Australia and France, 13 subsidiary companies and with representation in all countries of the world, has retired from the Board and the position of managing director, after 35 years of service with the Company. **Mr. J. A. Wykes,** deputy managing director for the last eight years, has been appointed to succeed Sir Charles, with effect from 5th April.

Mr. P. J. Daglish, A.M.I.E.E., has been appointed manager of the aircraft equipment division of the English Electric Co. Ltd., Bradford.

Mr. J. N. Dean has been appointed deputy chairman of The Telegraph Construction & Maintenance Co. Ltd., Telcon Works, Greenwich, London, S.E.10. The executive duties of the Board will no longer be vested in a managing director, but will be carried out by a managing board, of which Mr. Dean, as chief executive, will be chairman.

Mr. C. A. Edwards has been appointed sales manager of Bryce Berger Ltd., Staines, Middlesex.

Mr. J. S. Elliott, M.I.P.E., Principal of Gateshead Technical College, has been appointed Principal of the Rutherford Technical College, Newcastle-upon-Tyne.

Mr. R. K. Evans, A.C.G.I., A.M.I.Mech.E., has been appointed senior engineer of C. MacKechnie, Jarvis & Partners, 34 Victoria Street, London, S.W.1.

Mr. C. L. G. Fairfield, M.A., M.I.E.E., A.M.I.Mech.E., Barrister at Law, has been appointed general sales manager of The Telegraph Construction & Maintenance Co. Ltd., Telcon Works, Greenwich, London, S.E.10, responsible for the sales of cables, plastics and engineering products. **Mr. E. H. Gosling, A.S.M.A.,** has been appointed home sales manager for these products. Mr. Fairfield has also been appointed a director of Telcon Telecommunications Ltd.

Mr. Ambrose Firth, chairman and joint managing director of the Brightside Foundry and Engineering Co. Ltd., Sheffield, has been re-elected President of the Sheffield and District Engineering Trades Employers' Association.

Mr. G. E. H. Hall, A.M.I.P.E., has been appointed general manager of Sheepbridge Stokes Ltd. and British Van der Horst Ltd., members of the Sheepbridge Engineering Group. **Mr. R. Gore** has been promoted to the position of works manager of Sheepbridge Equipment Ltd., Chesterfield.

Mr. V. P. Harries, C.B., the new Under Secretary (Contracts) at the Ministry of Supplies, has been appointed to the Board of Power Jets (Research and Development) Ltd., in succession to **Mr. W. F. Jenkins, C.B., C.B.E.,** who resigned from the Board on his appointment to the Department of Atomic Energy.

Mr. D. D. Hawley, M.C., has been elected to the Board of Hadfields Ltd., Sheffield, 9, as sales director of the Company.

Sir Rex Hodges, whose retirement from the position of general manager and secretary of the Mersey Docks and Harbour Board has been announced, is joining the Board of British Insulated Callender's Cables Ltd. as from 31st March, 1954.

Mr. L. W. Honey, Assoc.I.E.E., and **Mr. L. J. Gooch, A.M.I.E.E.,** have been appointed joint managing directors of Marryat & Scott Ltd. Mr. Honey will operate from the firm's Wellington Works, Wellington Road South, Hounslow, Middlesex, and Mr. Gooch from the London office at 40 Hatton Garden, London, E.C.1.

Mr. K. R. Laurence has been appointed general manager of Winston Electronics Ltd., Hampton Hill, Middlesex.

Mr. Alexander McDonald, B.Sc., M.I.C.E., has been appointed secretary of the Institution of Civil Engineers, Great George Street, London, S.W.1, in succession to **Mr. E. Graham Clark, C.B.E., M.C., M.Sc., M.I.C.E.,** who will be retiring this year.

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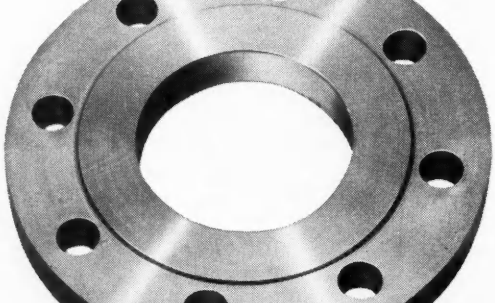

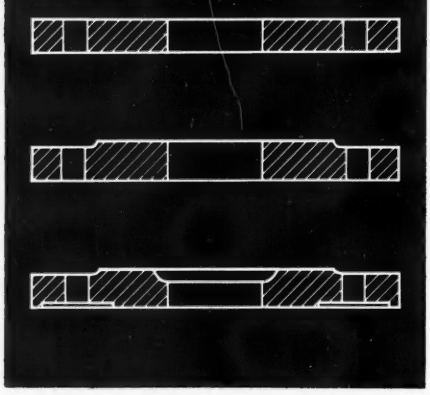

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Mr. John E. Markes has been appointed managing director of Bowden (Engineers) Ltd., Willesden Junction, London, N.W.10, in succession to **Lt.-Col. H. G. Gilchrist, D.S.O., M.C., M.I.Mech.E.,** who has retired from active business. **Mr. Markes** and **Mr. W. A. Melsom, M.B.E., A.M.I.Mech.E.,** directors of Bowden (Engineers) Ltd., have been elected to the Board of Bowden (Holdings) Ltd., the parent company.

Mr. A. A. Paget, A.M.I.Prod.E., chief planning engineer, has been released from W. and T. Avery Ltd., to take up appointment as works manager with Vandome & Hart Ltd., North London Ironworks, London, N.1.

Dr. R. W. Powell has been appointed senior principal scientific officer, Physics Division, National Physical Laboratory, in succession to **Dr. Ezer Griffiths, O.B.E., F.R.S.,** who has retired under the age limit.

Mr. Leslie M. Reay, M.B.E., has been appointed London sales manager for the electric motor division of Newman Industries Ltd., Yate, Bristol.

Mr. F. J. Robins, sales director of Major, Robinson & Co. Ltd., Manchester, has been elected to the Board of the company. Mr. Robins is in charge of the firm's London office at Evelyn House, 62 Oxford Street, W.1.

Mr. W. Sampson, B.A., A.M.I.E.E., has been appointed executive director of Telcon Telecommunications Ltd., owned jointly by Mullard Ltd. and The Telegraph Construction & Maintenance Co. Ltd., in succession to **Mr. J. Innes, C.B.,** who has relinquished the managing directorship and his directorship, but will continue to act as a consultant to the Board.

Mr. H. C. Shaw has been appointed engineering manager of J. Samuel White & Co. Ltd.

Mr. W. D. Stiven has been appointed commodore chief engineer of the Peninsular and Oriental Steam Navigation Co. Ltd., 122 Leadenhall Street, London, E.C.3.

Mr. E. E. Walker, A.M.I.E.E., publicity manager of Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester 17, has been elected chairman of the Trade, Technical and Vigilance Committee of the Incorporated Society of British Advertisers, in succession to Mr. Douglas Wilson, publicity manager of the United Steel Companies Ltd., Sheffield.

Mr. E. R. Wilkinson, commercial manager of the British Electricity Authority, will assist, at the request of the Government and with the consent of the B.E.A., the International Bank for Reconstruction and Development, in the appraisal of certain international electrical power developments.

Mr. F. N. Woods, M.A.M.E.M.E., M.I.E.S., has relinquished the duties of superintendent, Lamp and Lighting Department of Metropolitan-Vickers Electrical Co. Ltd., London, but remains available for consultation until the end of March. **Mr. S. G. Turner, F.I.E.S.,** has been appointed superintendent of the Lamp and Lighting Department in London, and **Mr. J. J. Berry**, superintendent of the Lamp and Lighting Department in Cardiff.

ELECTRICAL POWER CONVENTION

The promotion of the development of the home and overseas markets for electricity and electrical appliances is to be the theme of the sixth British Electrical Power Convention which is to be held at Eastbourne from June 14th to 18th, 1954. Delegates from 37 electrical organisations from all parts of Great Britain, Northern Ireland, Isle of Man and the Channel Islands, will meet under the presidency of Mr. J. R. Beard, C.B.E., M.Sc., M.I.C.E., M.I.E.E., F.A.I.E.E., who represents the Association of Consulting Engineers.

A large and most comprehensive electrical exhibition will be "housed" in a mammoth marquee covering 24,000 square feet of the Winter Garden grounds, within 200 yards of the Convention meeting place.

The Exhibition will be officially opened on the night of Monday, 14th June, by the President, Mr. J. R. Beard. The Convention and the Exhibition should bring some 2,500 visitors to Eastbourne.

The preliminary programme provides for the opening of the Convention on Tuesday 15th June, with a civic welcome from the Mayor of Eastbourne, followed by the Presidential address. After the annual luncheon of the Electrical Association for Women in the Grand Hotel, the Convention will resume in the Winter Garden when a paper on "The Market for Electrical Appliances and the Interdependence of Home and Export Trade" will be given by Sir George Nelson, F.C.G.I., M.I.Mech.E., M.I.E.E., British Electrical and Allied Manufacturers' Association. In the evening the delegates and their ladies will be the guests of the Mayor and Mayoress of Eastbourne at a reception in the Winter Garden.

On Wednesday, Mr. W. J. Jones, M.Sc., M.I.E.E., director of the Electric Lamp Manufacturers Association, will speak on "Modern Lighting for Industry, Commerce and the Home" and Dame Caroline Haslett, D.B.E., J.P., Comp.I.E.E., Director, Electrical Association for Women, will deal with "Electricity in the Modern Home." Both these talks will be accompanied by demonstrations.

On Thursday, a paper entitled "The Development of the Domestic Electricity Load at Home and Overseas" will be given by Mr. D. Bellamy, O.B.E., D.L., F.A.C.C.A., F.C.W.A., Comp.I.E.E., F.R.Econ.S., F.S.S., Chairman of the Yorkshire Electricity Board. In the afternoon, Mr. S. L. M. Barlow, Assoc.I.E.E., M.A.I.E.E., London, President of the Electrical Contractors Association, will speak on "The Comparison of Installation Practice at Home and Overseas." The Convention dinner in the Grand Hotel will conclude Thursday's proceedings.

On Friday morning two hours will be given to the popular "electrical forum" when questions are answered by a panel of

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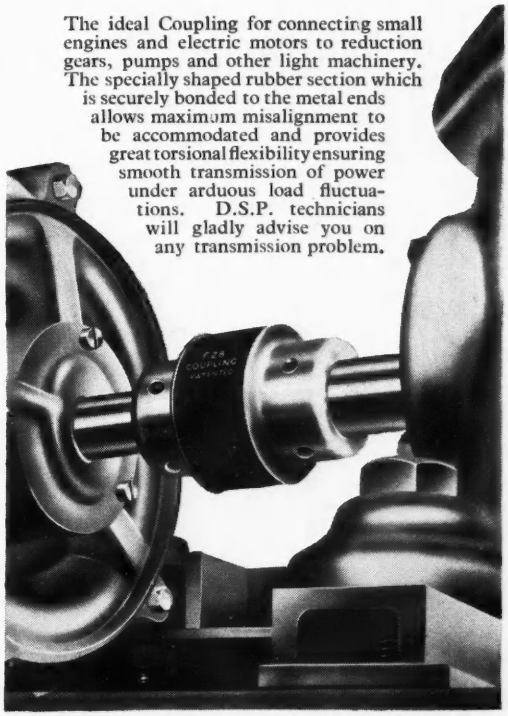

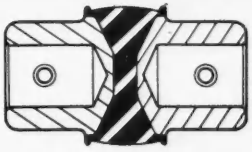

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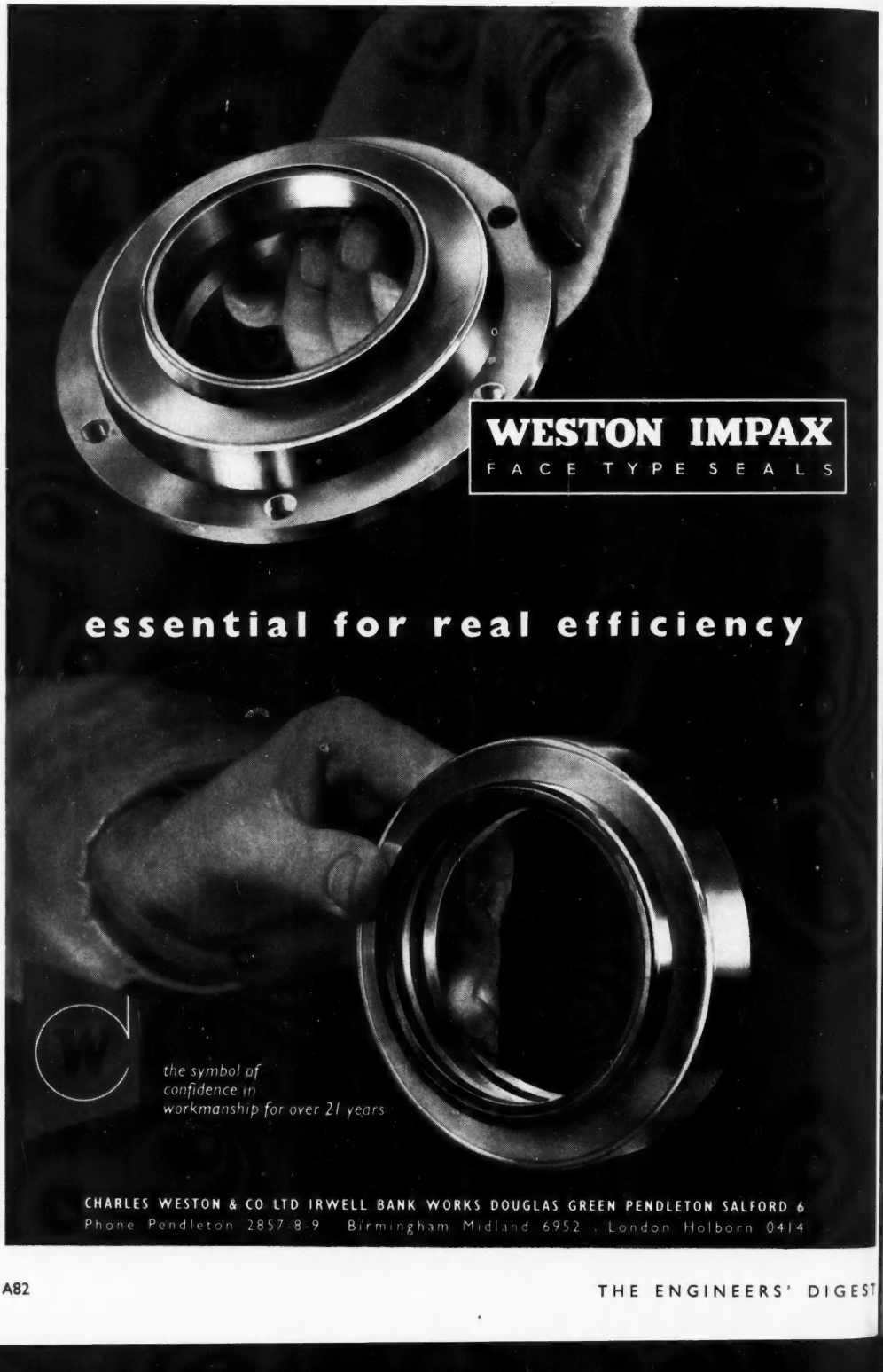
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experts with the President acting as question master. This is followed by the annual general meeting, at which officials for the next year are elected and the venue for the 1955 Convention is decided.

RADIO COMPONENT SHOW

There will be 130 exhibitors in the 11th British Radio Component Show to be held at Grosvenor House, London, from April 6th to 8th, 1954. This annual exhibition is organised by the Radio and Electronic Component Manufacturers' Federation, 22, Surrey Street, Strand, London, W.C.2, from whom invitations may be obtained.

The exhibits comprise British-made components for the radio, electronic and telecommunication industries, as well as gramophone components, valves and test gear.

The following are extracts from early information received about exhibits :—

New valves for the new British television frequencies (Band III) and VHF FM reception.

Claimed to be the first wide angle electrostatically focused tube to be manufactured in Britain, featuring semi-automatic focus, eliminating the need for an external focus coil or magnet.

A new 21 inch TV tube giving nearly twice the area of the 17 inch tube.

Dual magnet focus unit made more compact than hitherto and incorporating a less expensive method of picture positioning for use in low cost TV receivers.

New focusing unit departing from the use of ring magnets.

Multi-channel turret TV tuners.

Aerials for sound radio, including FM, and for TV.

A coupler specially designed for use with centimetre link equipment and possibly other applications.

Demonstration of reduction of residual cable noise by a factor greater than 50 : 1 following special treatment of inner and outer surface of the core insulant.

Wire-end terminals in 150 different sizes.

New 50 ohm helical membrane coaxials and a new 75 ohm cable of 1¼ in. diameter.

Air-spaced articulated cable, claimed to be closely approaching the ideal 100% air-insulated concentric line.

A hermetically sealed 5-watt rheostat potentiometer, stated to be the only potentiometer of its type fully approved to " H.1," the highest Service Specification for resistance to temperature (minus 60 deg. C. to plus 100 deg. C.) and humidity.

Sine/Cosine potentiometer 20K-30K to an accuracy of plus/minus 1%.

A new rotary main switch combining a number of micro-sensitive switches which can be ganged together in any number up to 12 units. It is compact and small and switches up to 750 watts per section.

Four-channel composite control unit for 3-D sound.

Apparatus illustrating applications of transistors.

Germanium junction power rectifier a quarter of the size of the present metal rectifier with electrical efficiency of 99%.

Silicone mouldings for heat stability, polyester resins for potting miniaturized circuits.

Nylon mouldings, large injection mouldings such as radio cabinets made from medium impact polystyrene as opposed to articles formed from glass fibre impregnated mat.

Extruded insulation in two and three colours, spirally applied—giving colour in depth, not by surface printing.

Terylene as insulation for copper conductors and resistance wires for operation up to 130 deg. C.

A new transcription motor and ceramic pick-up, to be in production soon, suitable for tropical use.

Tape recordings at a variety of tape speeds. Tape monitor for long duration air/ground communications.

New microphones. High fidelity power speaker for large gatherings.

A new stable high permittivity ceramic for by-pass capacitor manufacture.

Miniature metallised paper capacitors for use up to 85 deg. C.; thermetic metal cased midgets for operation from minus 100 deg. C. to plus 120 deg. C.

Variable condensers in range of 16 standard patterns covering the whole electronic field from miniature receivers to transmitting types up to 5,000 V test.

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Complete soldering and fluxing process for printed circuits and an automatic soldering head for repetition soldering processes.

Photo-electric cell measuring ¼ in. by ⅜ in., so sensitive to light that it will operate a relay direct without any form of amplification.

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A range of small diameter ceramic tubes, the smallest being 0·018 in. (0·45 mm) diameter with a bore of 0·004 in. (0·1 mm), suitable for temperatures up to 1600 deg. C.

Electronic gauge used in guided missile and supersonic flight research, capable of rapid measuring and calibrating machine parts to a few millionths of an inch.

New nickelising technique for bushes and seals.

HYDRO-ELECTRIC GENERATORS FOR SPAIN

The first of two of the largest high-speed salient pole generators ever manufactured in Great Britain has recently been completed at the BTH Rugby Works, for the Artias Hydro-electric Power Station, Spain. These 36,000-kVA machines, which are for horizontal operation, are each to be driven at 600 rpm by an overhung Pelton wheel at each end, and are designed for a runaway speed of 1100 rpm.

Important features of the generators are their exceptionally high efficiency and high flywheel effect, the former being guaranteed under heavy penalty. An efficiency figure of over 98·2% was obtained on tests, this representing a comfortable margin over the guarantee figure.

The station is situated in the Pyrenees at a height of more than 3700 ft. above sea level and consequently, due to transport difficulties, an interesting mechanical design of rotor was adopted. A stub shaft is bolted at each end of a pre-stressed hollow forging which forms the centre hub to which each pole is secured by four dovetails. All poles and both stub shafts will be removed before the machines are shipped to site, and even so the centre hub will be only just within the maximum transport weight of 40 tons.

The rotor of the first machine was tested at 1100 rpm in the new overspeed test house recently completed at the BTH Rugby Works.

CERTIFICATION MARK SCHEME FOR ZINC ALLOY DIE CASTINGS

The British Standards Institution and the Zinc Alloy Die Casters Association have together drawn up a Certification Mark scheme for zinc alloy die castings. This means that customers can order castings guaranteed to be made under strictly controlled conditions subject to inspection by the B.S.I., and complying with the exacting requirements of British Standard 1004. This standard was published in 1942 to safeguard the quality of the millions of critical ammunition components being made from zinc alloy die castings.

Zinc alloy die casting is a quantity production process used in many industries to make parts, often complicated in design, which are strong and durable. To ensure that these qualities are realized to the full, it is absolutely essential to use only zinc alloys of carefully controlled composition. If certain impurities, notably lead, tin, and cadmium, are allowed to contaminate the alloy—even to the extent of a few parts in 100,000—the future behaviour of the castings becomes uncertain. Already in many foundries a strict routine is followed so that each year millions of reliable zinc alloy die castings are made for use in motor cars, electrical equipment, household fittings, light and heavy engineering components, and defence stores. But some customers are still not aware of the dangers they run by being " penny-wise " about zinc alloy die castings, and some firms are still prepared to supply cheap off-grade castings to the unwary or indifferent buyer.

The purpose of the Certification Mark scheme is to give the customer a guarantee that if he orders die castings from a firm licensed under the scheme, he will recieve reliable castings complying with British Standard 1004. Wherever possible the castings will carry the Kitemark " B.S. 1004 " and the die caster's name, trade-

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NON-FERROUS METALS

Since the war years, many people, especially in the aircraft industry, have regarded the machining of non-ferrous metals as our particular province. With the formation of a separate metal division we are now able to place our unrivalled experience in this field at the service of industry. We can now quote reasonable deliveries on the range of machines listed. Our advice on your own non-ferrous machining problems is free on request.

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Light Radial Routers
Heavy Fixed Head Routers
Light Fixed Head Routers
Light Radial Tappers
Cut-Off Saws
Band Sawing Machines
Spindle Shapers

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mark, or B.S.I. licence number. Castings too small to be marked individually will be supplied in specially labelled boxes.

The new Certification Mark scheme will be widely publicised both by individual licensees and by the Zinc Alloy Die Casters Association, which has sponsored it. Many firms have already had their works inspected by the British Standards Institution and have been granted licences to use the Kite-mark. The Association's own advertisements will include a list of members who are licensed and the list will be kept up-to-date as other members come into the scheme.

If the B.S.I. finds that a licensee is supplying castings outside the specification, he will be warned and, in persistent default, will forfeit his licence. Participation in the scheme is open to any die caster, whether or not a member of Z.A.D.C.A., who is willing and able to comply with the conditions. Full particulars are obtainable from The British Standards Institution, 2 Park Street, London, W.1.

The American Die Casting Institute introduced a certification scheme for its members in 1949, and this has been very successful in reducing the proportion of poor quality castings sold. The industry in the U.S.A. consumes about a quarter of a million tons of zinc alloy annually, and is about ten times the size of that in Britain, which is itself the world's second biggest producer of zinc alloy die castings. As in Britain, the main use for these castings is in the automobile industry, and many American cars incorporate a total of 100 lb of them in mechanical and electrical parts and chromium plated trim.

Though it would be unreasonable to expect that the British zinc alloy die casting industry will ever reach the size of that in America, it is clear that it could make a much greater contribution to British productivity than it has done yet; the consumption of zinc alloy die casting per head of population is ten times as great in the United States as it is in Britain. The Zinc Alloy Die Casters Association is confident that the guarantee of quality obtained by ordering certified zinc alloy die castings bearing the B.S.A. Kite-mark will encourage manufacturers of all kinds of goods to take more advantage of this highly economical process.

NEW FORD DIESEL ENGINE

A new diesel engine is now in production at Ford Works, Dagenham. It has been designed as an alternative to the petrol engine for the 2 and 3 ton range of Thames commercial vehicles It is of 3.61 litres capacity, 4-cylinder, developing 60 bhp at a governed speed of 2,400 rpm.

Ford production methods and design have made it possible to provide this engine at a basic price which is only £85 extra in the case of the 2 ton models, and £100 extra for the 3 ton models. The engine in both cases is identical, but servo assisted brakes with exhauster equipment are standard on the 3 ton vehicles.

Never before have the advantages of diesel operating economy been made available at such low initial cost, a cost which in the case of the average commercial vehicle user it is possible to recover—in economy on fuel alone—during the first year of service.

The engine has been designed specifically to transport 2 and 3 ton loads in the most efficient and economical manner. Direct injection, a sturdy 5-bearing crankshaft and wet cylinder liners are some of the design features contributing towards long engine life.

Developing 150 lbs/ft torque at 1600 rpm with over 140 lbs/ft between 880 and 2200 rpm excellent top gear performance is assured. Thus the use of intermediate gears is minimised and good average speeds can be maintained.

Ease of maintenance and accessibility have been carefully studied in the design. The layout of the engine compartment and the a ligator type bonnet make all items of the fuel and oil systems, rockers, dipstick and butterfly adjusters readily accessible.

Ford service facilities are available through the Ford Dealer Organisation with repairs at low fixed charges and adequate supplies of spare parts.

Prices of the complete Thames 2 and 3 ton commercial vehicles with the new Ford diesel engine range from £792 including purchase tax for the 2 ton 128 in. wheelbase truck to £910 for the 3 ton 157 in. wheelbase truck and £1,005 for the 2 ton van.

INDUSTRIAL ELECTRONICS CONVENTION

The whole of the 1954 Brit. I.R.E. Convention will be devoted to the application of electronics to industrial controls, processes and computation.

The Convention will be held in Christ Church, University of Oxford, from July 8th to July 12th. Residential accommodation will be provided in the College.

The programme is divided into 6 sessions which include "Industrial Applications of Electronic Computors," "Electronic Methods of Testing" (X-rays, ultrasonics, radioactive devices, etc.), "Electronic Control" (transducers, actuators, motors control, magnetic amplifiers, welding, etc.).

The final session will be entirely devoted to a discussion on "How electronics can increase production" which will be opened by Sir Walter Puckey, President of the Institution of Production Engineers.

BUSINESS NOTES

Albright and Wilson Ltd., 49 Park Lane, London, W.1, announce that their new factory at Portishead, near Bristol, has now commenced production. **Mr. J. A. McArthur** is resident works manager.

Bruce Peebles & Co. Ltd., Edinburgh 5, announce that their London office is now at 54 Victoria Street, London, S.W.1. Telephone: TATe Gallery 3551/4.

"Bicaloy" Electrode Tips continue to be manufactured by British Insulated Callender's Cables Limited. Although the manufacture of their resistance welding and heating machines was recently taken over by Metropolitan-Vickers Electrical Company Limited, the arrangement does not affect "Bicaloy" welding tips which are still made and supplied by B.I.C.C.

Payne & Griffiths Ltd., Tudor Works, Windmill Lane, Smethwick, Birmingham, announce that their London office is now at Broadway Court, 8 Broadway, London, S.W.1. Tel.: ABBey 4616/7. Mr. R. W. Kerridge has been appointed manager of the London office.

Mono Pumps Ltd. have removed their service and sales departments to more extensive premises. The new address is Mono House, 1 Sekforde Street, London, E.C.1.

James Neill & Company (Sheffield) Limited, a private family business manufacturing alloy and special steels, permanent magnets, hacksaw blades and other tools, has acquired from the Iron & Steel Holding and Realisation Agency the whole of the issued share capital of the Hallamshire Steel & File Company Limited.

The acquisition will not lead to any change in the existing management of the Hallamshire Steel & File Company Limited. **Mr. B. Wasden** will continue as managing director, and **Colonel J. P. Hunt** (who until joining the Staveley Coal & Iron Company Limited on the 1st January 1954 was chairman and managing director) and **Mr. H. W. Waterhouse** will remain on the Board. **Colonel F. A. Neill,** chairman & managing director, **Mr. J. H. Neill** and **Mr. P. Neill,** directors, and **Mr. R. Firth, A.C.A.,** secretary, of James Neill & Co. (Sheffield) Ltd., will join the Board. **Colonel F. A. Neill** and **Mr. J. H. Neill** will become chairman and deputy chairman respectively of the new Board.

It is not intended to make any change in the general policy of the Hallamshire Steel & File Company Limited, but the merging of its steel rolling interests with the steel melting interests of James Neill & Company (Sheffield) Limited will be to the mutual benefit of both companies.

The General Electric Co. Ltd., which has been represented in Malaya for nearly 50 years, has opened new premises in Singapore to give South East Asia improved service over the whole range of the Company's products. The event is an indication of the expansion of its interests and investments in Singapore and Malaya, which now comprise an organisation employing 350 people. The new Magnet House, with modern showrooms, stores and offices in addition to servicing workshops, is situated in Bukit Timah, Singapore 10. It has two storeys and provides more than 80,000 sq. ft. of floor space. It was officially opened at the end of January by Mr. Leslie Gamage, M.C., vice-chairman and joint managing director of the G.E.C.

THE RECIPROCATING TOGGLE THEN ACTUATES THE PLUNGER IMPELLER

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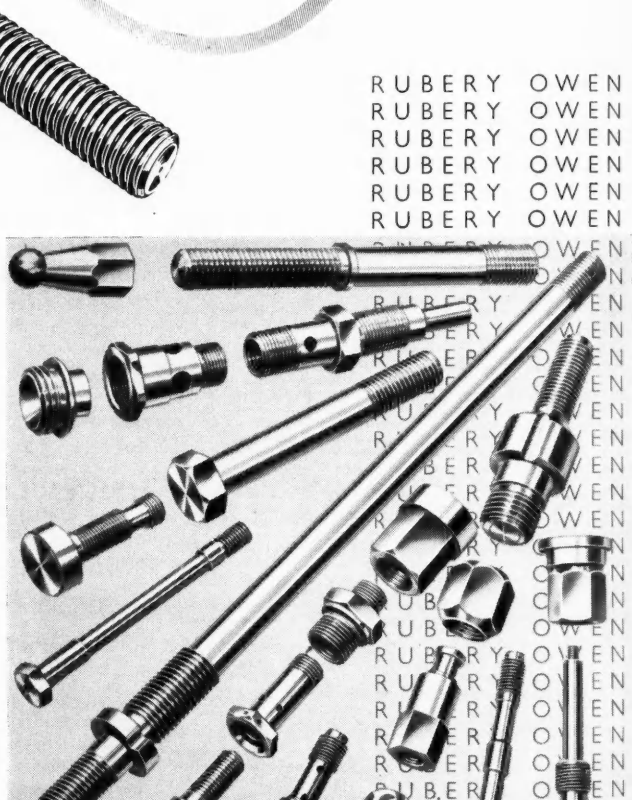

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The Industrial Division of Philips Electrical Ltd. announce the completion of their new film " A New Approach to Production Improvement," made with the co-operation and help of 17 widely differing industrial undertakings. This black and white sound film, which runs for approximately 50 minutes, is meant to be part of the " Philips In The Service of Industry " policy, typified by the extensive facilities offered at the Philips Application Centre, London.

The film is made for those who are interested in seeing how widely varying products are manufactured, and how modern methods of production are applied to improve output and quality. But not only production methods are dealt with in this film. Considerable emphasis is also given to the means Industry employs to evolve new and better methods, and how Industry remains in contact with the latest developments in production equipment, adapting it to fulfil specific needs.

Every attempt has been made to make the film as interesting to a technical audience as to a semi-technical or lay audience. The engineer has become highly specialised even within his own field. He will welcome the quick yet accurate insight afforded by this documentary film into what others are doing in his or other branches of Industry.

Since, on the whole, only the main features of a process or application are drawn, the student or semi-technical viewer, too, will find much to interest him.

Copies of this film are available in 16 mm. and 35 mm. sound, black and white. They will be loaned free of charge to Film Societies, Engineering Societies, Technical Colleges, Industrial undertakings, etc. Applicants are requested to inform Philips as early as possible of the date on which they require the film. Please write for a booking form to the Industrial Application Centre, Philips Electrical Ltd., 122 Brixton Hill, London, S.W. Tel. No. Tulse Hill 4652.

Teddington Industrial Equipment Ltd. have opened their Midland area offices at 107 Dale End, Birmingham. Tel.: Central 4791/2. Mr. V. C. Miles, who has represented the Company for the last few years, is in charge of the new offices.

Thompson Brothers (Bilston) Ltd., Bilston, Staffordshire announce that their London office has been transferred to 17 Surrey Street, Strand, London, W.C.2. Telephone: COVent Garden 1701.

David Brown (Australasia) Pty. Ltd., Sydney, have acquired a modern factory at North Lidcombe, N.S.W., Australia, which will be Headquarters of the company.

Elliott Brothers (London) Ltd., Century Works, Lewisham, London, S.E.13, have concluded a licence and technical agreement with the Bristol Company, Waterbury, Conn., U.S.A., and have acquired the business of Bristol's Instrument Co. Ltd., Weymouth. Under the new arrangement, Bristol process-control instruments will be manufactured in the United Kingdom.

Kerry's (Great Britain) Ltd., Warton Road, London, E.15, have opened a sales office at 87/89 Edmund Street, Birmingham 3, to deal with their machine tool activities. **Mr. J. Steward,** area manager, will be in charge of the Birmingham office.

Permali Limited have appointed Mr. R. Ian Douglas as their technical representative (Railway Engineering). Mr. Douglas will operate from the Company's London office, 54 Victoria Street, London, S.W.1. Tel. No. ABBey 6494, and will be responsible for the sale and development of Permali track circuit insulating joints and other signalling and permanent way equipment produced by the Company.

The Lille International Trade Fair will be held from May 1st to 16th, 1954. The Fair occupies an area of about 240,000 sq. yds., including covered halls of gigantic dimensions. The Grand Palace itself covers an area of about one hectare. There will be 3,500 exhibitors from 15 countries. 1,500,000 visitors are admitted each year.

The Oil Committee of the Organisation for European Economic Co-operation has undertaken a study on the search for and exploitation of crude oil and natural gas in Member countries, a problem of great importance to the economy of Europe. The main points to be studied are: Geological information, mining and fiscal regulations, current operations and operating resources in Europe. This is a new activity for the Oil Committee, which up to now has been chiefly concerned with co-ordinating the development of refinery capacity and making periodical surveys of trends in the production and consumption of petroleum products.

The study will be of great assistance to governments desirous of encouraging the search for and exploitation of crude oil and natural gas in their own territories, since it will provide them with detailed information on the results obtained in other countries. It should also give practical guidance to private investors in oil prospection in Europe.

A Tonnage Oxygen Unit for producing the vast quantities of oxygen required for the direct flash smelting of copper concentrates has been placed in operation by The International Nickel Company of Canada Ltd., Copper Cliff, Ontario. Inco's new oxygen flash smelting process eliminates the fuel normally required for smelting and makes economical the present large-scale output by Canadian Industries Limited of liquid sulphur dioxide from furnace exhaust gases.

International Nickel's operations call for a volume of more than 7,500,000 cubic feet of oxygen every day—enough to fill 32,000 standard cylinders. This requires the production of 300 tons of 95 per cent pure oxygen every 24 hours.

The oxygen plant, designed and built by Canadian Liquid Air Co. Ltd., and known as an " Oxyton," separates the oxygen from atmospheric air by the liquefaction process, using the same basic principles as apply in smaller commercial oxygen plants. The air is first liquefied under pressure in a series of compressors, regenerator-heat exchangers, distillation columns and other equipment, and then the oxygen is separated from the other constituents of the atmosphere—nitrogen, argon, neon and krypton. The oxygen is carried as a gas through a 16-inch diameter elevated pipeline from the Oxyton to the smelter, a distance of 6,000 feet.

As temperatures of a few hundred degrees Fahrenheit below zero are involved in the liquefaction process, special consideration had to be given to the types of metals and other materials employed in certain parts of the oxygen generating unit. For example, the important regenerator-heat exchanger system consists of two nitrogen regenerators, each eight feet in diameter and 17 feet long, and two oxygen regenerators, each four feet in diameter and 14¾ feet long. While one pair of regenerators chills the incoming air, the other pair is being chilled by the separator gases. Working temperatures range from 80 deg. F to minus 280 degrees. Since most ferrous metals suffer a marked increase in brittleness at sub-zero temperatures, the regenerators were made from special 8½ per cent nickel steel, developed by International Nickel for low temperature use. Incidentally, the regenerators are of welded fabrication, type 310 stainless steel electrodes being employed.

Two other interesting pieces of equipment in the oxygen plant are a specially built oxygen compressor and a huge turbo compressor (required for the initial compressing of the air), one of the largest of its kind in the world.

Despite its size and intricacies, the operation of the Oxyton is essentially automatic, once the liquefaction process has been started. Control and metering are carried out by modern electronic equipment with over 40 control instruments centralised on a huge operating panel—the nerve centre of the plant.

The far-reaching possibilities of large-scale oxygen applications in metallurgical and chemical industries have been recognized within recent years by leading research scientists. Their studies lead to the conclusion that oxygen, employed in tonnage volumes, will transform many industrial processes within the next generation, with International Nickel among the leaders pointing the way.

Steel for Concrete Reinforcement. The Tentor Bar Company Ltd., of 43 Upper Grosvenor Street, London, W.1, a member of the Guest, Keen & Nettlefold Group, has introduced to the British market a new type of bar reinforcement for concrete.

Originally produced in Denmark, and now manufactured in England under licence from the Danish patentees, the Tentor bar, before processing, is a hot-rolled round bar, with two parallel longitudinal ribs and transverse diagonal ribs arranged in a herring-bone pattern. The bar is subjected to two different types of cold working, i.e., a longitudinal stretching process, which increases the strength throughout the whole section of the bar, and a twisting process which produces a further increase in strength in the outer fibres. The transverse ribs are arranged so that the sectional area of the bar is uniform throughout its length. The projection of the ribs above the general surface of the bar, and the spacing of the transverse ribs, are such that, in concrete of normal quality, high bond stresses are developed between the steel and the concrete.

The bar is rolled from mild steel in accordance with B.S. 785, having an ultimate strength of 28-33 tons per square inch. The Tentor process increases the tensile strength of the bar and yield point is eliminated. The bars are processed in lengths of 130 ft in a fully automatic machine. Special plant has been installed at the rolling mills of G.K.N. (South Wales), and these bars will also be produced later this year by the United Steel Companies and by McCall & Co. (Sheffield).

Classified Advertisements.

The rate for all classified advertisements is 6d. per word; in bold print 9d. per word; minimum order 6s. Box number advertisements 1s. extra. Instructions together with remittance must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.

SITUATIONS VACANT

YOUNG ENGINEERS. The Hymatic Engineering Co. Ltd., Redditch, require young engineers with degree in Mechanical Engineering or Physics or with H.N.C., for interesting and instructive work in development of mechanical, electrical and fluid mechanisms for aircraft and industrial applications. Some industrial experience desirable but not essential. Pension Scheme. Excellent conditions. Apply with full details to Technical Manager.

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GRAVITY DIES, designed, manufactured and proved. **R. E. Ormerod Ltd.,** Ednall Lane, Bromsgrove.

RECONDITIONED EX-ARMY HUTS, and manufactured buildings. Timber, Asbestos, Nissen Type, Hall Type, etc. All sizes and prices. Write, call or telephone—**Universal Supplies (Belvedere) Ltd.,** Dept. 50, Crabtree Manorway, Belvedere, Kent. Tel.: ERITH 2948.

WANTED.—Copies of the March, 1953 issue of " The Engineers' Digest " urgently required. Also Jan., 1949, June, 1950, and Dec., 1951, issues at 3/6 per copy.—Subscription Dept., 120, Wigmore Street, London, W.1.

LATEST INDUSTRIAL LITERATURE

1. Hand-Surfacing Tool. A leaflet describes a new file-type hand-surfacing tool which works faster than rasps and files on all materials up to the hardness of mild steel, such as wood, rubber, leather, fibre, plastics, copper, aluminium, and lead.

The tool has a high-quality carbon steel cutting strip, with 500 separate blades, each with a 35 deg. cutting angle; as a result, clogging cannot occur and, because the depth of cut is strictly controlled, it is possible for an unskilled user to work to craftsman standards.

A supplementary leaflet describes a similarly designed tool, but of the plane type, instead of the file type.

2. Pin Drilling Jig. The practice of drilling small holes through the corners, flats, or diameters of hexagon or round components, for locking wires, split pins, oil and pressure feeds, etc., has long been a costly tooling charge in relation to its function.

A new jig for this purpose, which replaces the use of numerous single-purpose jigs, is described and illustrated in a 4-page brochure. The inverted Vee design affords the perfect location needed for drilling small holes, thereby eliminating drill breakages caused by erratic starting or vibration. Furthermore, the hole centres (when drilling through the corners of hexagons) are adjustable to all variations and to any desired accuracy.

The jig, which can be set to drill most components within two or three minutes, has been designed for efficient swarf removal, and is adjustable for wear, low-cost replacement bushes being available from stock.

3. Self-Sealing Couplings. A self-sealing coupling, completely leakproof under all conditions, and with instantaneous cut-off, is described and illustrated in a 4-page brochure. It is particularly applicable to any industry where a rapid, simple, and low-priced coupling is required, and where the danger of fluid leakage, however small, is of first importance.

These couplings are suitable for use with all mineral-based fluids and in systems with working pressures up to 3000 psi.

4. Polymer Emulsion Paint. A leaflet describes a polymer emulsion paint, which is quick to apply and which dries in three hours. It is washable, non-toxic, free from odour, and contains an anti-mould growth agent. The paint has good flow and lapping properties, and can be applied satisfactorily to any surface, including new plaster, cement, asbestos board, etc.

This paint is produced to the colour range now used for flat oil wall paint and gives a satin finish in its normal formulation. It can, however, be produced with a matt finish, if specifically required.

5. Rigidhobber. An improvement in hobbing technique has resulted from the development of the rigidhobber described and illustrated in a neat 12-page publication. The new rigidhobber has been developed from a standard machine, the principal change being the addition of hydraulic cylinders on either side of the hob head slide, supplied from a self-contained hydraulic unit.

Features of the machine include rigid construction; automatic cycle; rapid power traverse, and continuous automatic axial traverse of the hob; centralised controls and one-shot lubrication; quick-release tailstock; climb or conventional cut hobbing; and adjustment of backlash between index worm and wormwheel.

6. Automatic Air Dryers. Details are given in an illustrated leaflet of a range of air dryers which fill the need for reasonably priced automatic equipment for the dependable drying of instrument air and other compressed air supplies.

These units, which are of robust construction, completely remove water vapour from compressed air. Air or gas passing through the apparatus is dried so thoroughly that moisture condensation inside the delivery line is entirely eliminated, thereby preventing the formation of rust and sludge.

7. Industrial Rubber Products. Useful information, practical ideas, and suggestions for the conservation of industrial rubber products are contained in a very well produced and profusely illustrated 32-page maintenance manual. Among other items covered in this interesting publication are the installation, inspection, care, and maintenance of conveyor belts, transmission belts, elevator belts, and V-belts, with notes on belt joining and fastening; and the installation, inspection, repair, etc. of hoses of all types, including fire, air, water, steam, and petroleum products.

8. Hydraulic Positioning Jacks. A leaflet describes a range of hydraulic jacks, primarily intended to speed up and to simplify the installation and alignment of heavy machinery, such as marine engines, machine tools, presses, turbo-generators, etc.

Basically, the equipment consists of a number of jacking units, having a closed height of only $1\frac{7}{8}$ to $2\frac{3}{4}$ in., depending on their capacity. These units are operated by one or more high-pressure hand pumps through a control manifold and suitable lengths of flexible piping. In addition to the positioning of heavy machinery, these jacks can also be used for many other purposes and, with the aid of simple tackle, may be employed for extracting coupling bolts or for forcing propellers and other fittings off shafts.

9. Gear Pumps. Details of two ranges of gear pumps are contained in an illustrated leaflet. One range is for oils and intended for medium-pressure applications to rams for the control of machine tools, factory handling plant, etc.; the other range is for water and similar liquids and is intended for industrial applications for water, dyes, mild acids, and mild alkalis.

These pumps are available in either foot-mounting or flange-mounting patterns. Packings are easily changed and are relieved from the full pumping load, thereby ensuring long life with reduced maintenance charges and avoidance of frequent plant stoppages.

10. Files. Specifications of and information on a comprehensive range of files for all purposes are contained in a 20-page catalogue. Included are useful illustrations and descriptions of engineers' and saw files; these should be of particular value in helping to identify particular files, the similarity of some types of which occasionally leads to confusion.

11. Miniature Pneumatic Valves. A 4-page brochure describes and illustrates a new range of miniature valves for pneumatic control, developed for pilot operation and sequence control where only a restricted movement is required. These valves are of neat and robust design, and are suitable for mounting on control panels or in confined spaces. They are available as 3-way exhausting or 4-way self-reversing valves, and are produced with many alternative methods of operation, including solenoid and foot.

Corresponding fittings and cylinders are also described in the brochure and, in conjunction with these valves, make a complete miniature range.

12. Electromagnetic Percolator. A range of wet-chute types of separators, highly suitable for the extraction of fine iron and magnetic oxides, where normal commercial standards of purity are required, is described in an illustrated 4-page folder. There is also a range of super-high-intensity separators, which incorporate an extra-large magnet system, providing exceptionally powerful magnetic fields, and which are recommended for applications involving the more feebly magnetic oxides.

These percolators incorporate features of design which ensure not only that the fluid has to pass through formidable magnetic barriers, but also that it comes into direct contact with innumerable magnetic edges—an essential for the efficient extraction of fine iron particles and magnetic oxides. Operation of these units is simple, power consumption is low, and maintenance is negligible.

13. Punching, Cropping, Slitting, and Notching Machine. A new punching, section-cropping, plate-slitting, and notching machine is described in a 4-page illustrated brochure. The punching slide is fitted with a new type of control, by means of which it is necessary only to pull out a knob to make it possible to lower the slide by hand lever, bringing the punch down, by hand pressure only, into contact with the plate to be punched.

A special feature of this machine is the unusually long pair of blades (20 in.) of the plate-slitting shears. Cropping is undistorted and the angle and tee-cropping blades are so designed that angles can be cut with a square or a bevel cut in any direction, without changing, moving, or adjusting the blades.

14. Internal Grinding Machines. Full details are given in a neatly presented and illustrated 8-page brochure of a range of internal grinders, with many special design features.

These machines are of two types, i.e., manual operation, without automatic measuring arrangement, for shops where repetition grinding jobs are not carried out; and fully automatic, for mass and quantity production. All main parts of both types are identical in design.

15. Roller Driving Chains. Specifications of a range of precision-made roller driving chains are given in an illustrated 4-page publication.

These chains are of particularly rugged construction, with an enhanced breaking load. They are normally available from stock, and are supplied with pitches from $\frac{3}{8}$ in. to $1\frac{1}{2}$ in. inclusive, in single duplex, and triplex series.

16. Marine Fans. In a beautifully produced 32-page publication, a range of marine fans, with examples of their application, is described and illustrated.

These fans are the first axial-flow marine fans to be developed for manufacture by modern methods. Besides offering high efficiencies, quietness, and compactness, they introduce many special advantages. New motors and control panels have been developed for these fans which, from start to finish, embody the requirements specified by leading marine engineers in the United Kingdom and in European countries. The basic factors in the system employed are a group of patent, adjustable-pitch impellers and a related group of interchangeable motors, made in sizes to conform with the impeller hub diameters. These permit a great many alternative air volumes and pressures in each fan diameter. Thus, for instance, each size of impeller can be set to twenty-five different blade pitch angles.

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *NITRIDING OF TITANIUM*

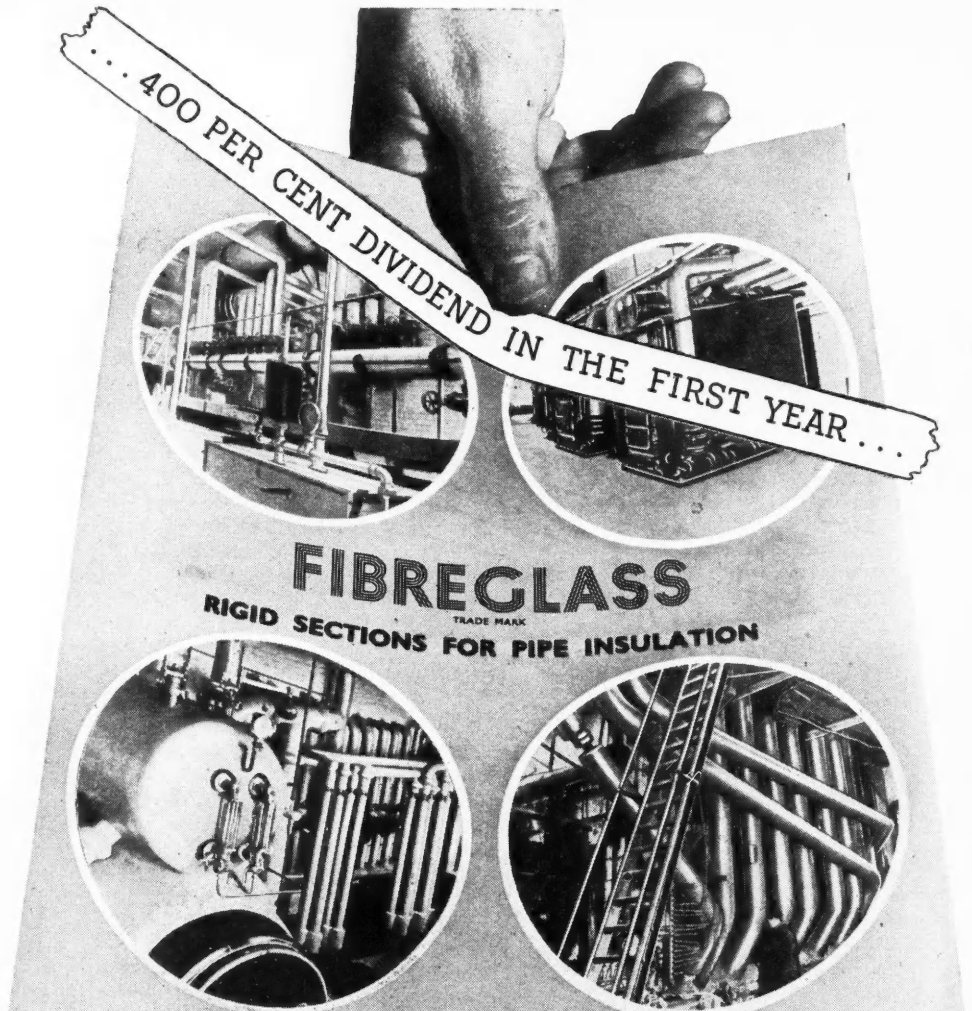
When assessing the usefulness of titanium as a constructional material, it is necessary to take into account the fact that its high strength, light weight, and corrosion resistance are unfortunately accompanied by low wear resistance and a marked tendency to gall and seize. To make titanium more widely useful, methods of overcoming these adverse properties must therefore be developed. Recent research in this direction has been concentrated upon cyanide, pack, and gas carburising, and straight nitrogen and ammonia nitriding. Of these various treatments, only ammonia nitriding was found to be a suitable means of producing commercially a suitable case on titanium. Liquid cyaniding resulted in serious corrosion and was not effective in producing a hard case. Pack carburising developed only an embrittled, oxidised skin and, while gas produced a carbide surface, it would not harden sufficiently to warrant exploitation. Nitrogen nitriding is less effective than ammonia, and its use would be limited in certain directions. Three major variables represent the controlling factors in the ammonia nitriding process, i.e., temperature, length of treatment, and gas purity. These three variables must be closely controlled in order to produce optimum hardening. It has been found that, for a given treatment, time, and temperature, there exists an optimum ammonia flow rate producing maximum diffusion. For each temperature a definite treatment time results in a maximum thickness of hard case on the metal surface. For longer periods of exposure, the case depth was found to decrease again and to approach a constant thickness of approximately 0·001 in. after three weeks. With regard to the aspect of gas purity, it was found that even small amounts of moisture in the gas result in thinner diffusion layers. Employment of a gas of high purity results in the production of a uniform patina, ranging from lemon yellow to dark gold.

● *X-RAY INSPECTION OF IRREGULAR PARTS*

In the radiography of jet-engine components, problems continually arise in handling parts of greatly varying size, shape, and weight. Considerable work is involved in the setting up and preparation of parts and films for X-ray exposure. The result is a lengthy and laborious set-up procedure, which must be repeated for every piece to be X-rayed. Jigs and fixtures for holding such parts as flanges, welded rings, and similar components are, of course, easily made available but the real problem lies in the supporting of smaller pieces of irregular shape while the X-ray exposure is carried out. An exceedingly simple piece of equipment has recently been devised which, besides being inexpensive and simple to operate, requires no special training or skill on the part of an X-ray technician. The equipment consists of a thin-walled rubber bag filled with fine plastic granules. Attached to the bag is a flexible hose, through which air can be evacuated by a portable electric vacuum pump. In its natural state the bag is very limp. When air is partially evacuated, it becomes as pliable as putty and can very easily be moulded to any desired shape. Upon further evacuation, the bag and its contents become extremely hard and hold any previously moulded shape. Because there is a point during air evacuation at which the bag becomes pliable, so that it can be shaped to any desired configuration, and because the bag can then be hardened to hold this particular shape, it can be made to serve as a universal jig and fixture, which not only holds the part in position under the X-ray tube, but also holds the film in place against the part. Radiography can be performed through the bag without difficulty, as the bag and its contents are transparent to X-rays, and in most cases can be moulded so that one shaping and evacuating sequence will suffice for the radiographic inspection of any number of like parts.

● *SELF-LUBRICATING HIGH-SPEED STEEL*

It has long been known that sulphur, usually in the form of manganese sulphide, when added to low-alloy steels, produces good machining properties. However, high-speed steels have relatively low manganese content, and additional manganese above about 0·5% will result in large amounts of retained austenite. The use of manganese sulphide does not, therefore, provide the desired effect, but it has been found that sulphur, added to the melt as molybdenum sulphide or as iron disulphide, or even as elemental sulphur, is soluble in certain molten high-speed steels to at least 2%. In amounts of less than 1%, sulphide is believed to solidify as part of a complex carbide-austenite eutectic. With regard to the adverse influence of sulphur upon forgeability and other hot-forming properties of high-speed steel, it has been found that, if the sulphur content is not too high, and



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melting and casting conditions are properly controlled, the decrease in workability is fairly small. The optimum amount of sulphur for the best combination of machinability, self-lubrication, formability, and mechanical properties after heat treatment is given as somewhere between 0·08% and 0·2%. Promising results are claimed to have been achieved with 0·12%. Tools made of this new type of high-speed steel exhibit improved cutting efficiency, owing to the lubricating action of the sulphide particles in the matrix of the steel. Sulphide additions improve machinability of the tool steel itself by the phenomenon of internal lubrication. Higher cutting speed and better machined surfaces are attained without materially affecting the type of chip generated.

● *LIGHT-SENSITIVE SWITCH*

A new device has been developed for controlling beacons and other signals which are intended to operate only at night, or which are required to operate differently during the day or night. The main component of the device is a pair of square, parallel bi-metal plates with different light-absorbing characteristics. These plates are supported adjacent to their edges, so that they can freely bend in the same direction, in accordance with relative temperature variations of the plates, and an electric switch is provided at their centre, this switch being actuated by the relative displacement of the plates. As long as the plates are at the same temperature, and provided a temperature rise deflects them to the same extent, the electric switch contacts are not operated. However, as one of the plates is made more light absorptive than the other, exposure to light will cause the more light-absorptive plate to attain a higher temperature and consequently to deflect more than the other less light-absorptive plate. The resultant difference in deflection will then cause the switch contacts to close or to open, as the case may be. The required difference in light absorptivity of the two plates is obtained by painting one plate a dull black and the other white, or by polishing it. In a device of this kind, it is, of course, highly important that there should be no variable friction effects which would influence the free bending movement of the plates. In the device referred to, the points supporting the plates are therefore mounted so as to have a certain degree of freedom to move in a plane parallel with the plates.

● *RECIPROCATORS WITHOUT PISTON RINGS*

Several proposals have been made in the past to eliminate the need for cylinder lubrication in steam engines and compressors by using closely fitting pistons kept out of physical contact with the cylinder walls. In order to minimise leakage losses, special designs, known as labyrinth-type pistons, were developed and extensive test data were obtained on experimental designs. One prominent engine builder even proposed to incorporate labyrinth grooves in both cylinder and piston. It goes without saying that maintenance in service of a constant close clearance between piston and cylinder wall requires the provision of highly accurate piston-rod guides. In order to preclude any tendency towards eccentricity from one-sided wear due to the weight of the piston, most of the designs proposed were based on the use of vertical cylinders. There is no doubt that a reciprocator with out-of-contact pistons would constitute an important advance, provided that the leakage losses could be kept low enough not to jeopardise engine efficiency. In the case of steam engines, for instance, such a design would make possible operation with superheated steam temperatures far above the present limit set by considerations of lubrication. A recent proposal is concerned with the use of out-of-contact pistons in pumps and compressors of the type in which the cylinders are arranged around a rotary central shaft, the piston rods being acted upon by the movement of a wobble plate on the central shaft. In this design, the piston rods are guided by journal bearings especially designed to be gas-tight. It is interesting to note that one modification of this design expressly envisages the use of labyrinth-type pistons.

● *PRODUCTION OF ADHERENT MOLYBDENUM DISULPHIDE FILMS*

It is well known that molybdenum disulphide used as a surface dressing acts as a lubricant and provides a low coefficient of friction in sliding or rubbing contact with iron and steel and certain other materials. Surface films of this kind are, however, generally not sufficiently adherent to ensure their permanent maintenance. It has therefore been proposed to incorporate molybdenum disulphide into a porous metallic structure, so as to provide a substantial reservoir which in use maintains a surface smear of molybdenum disulphide over the bearing surface. A recent invention aims at providing a molybdenum disulphide bearing surface in a different way. It is proposed first to provide the surface to be covered with a porous coating of molybdenum and then to subject this coating to a chemical treatment, converting the exposed molybdenum into molybdenum disulphide, which fills, or at least partially fills, the pores. The porous molybdenum surface can be produced by spraying molybdenum upon the parent surface with a spray gun. The conversion of the exposed molybdenum to molybdenum disulphide can then be effected by treatment with hydrogen sulphide at a temperature of 800 to 850° C. This invention is especially applicable to the production of steel-backed bearing liners. A particularly interesting feature of this invention is that the molybdenum disulphide film can be made self-healing when the bearing is used at elevated temperatures. This is achieved by

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maintaining sulphiding conditions in the bearing, which convert fresh molybdenum into molybdenum disulphide as the film wears away. For temperatures up to 200° C, a sulphiding compound in an oil or grease can be employed, but for higher temperatures a special gas must be passed through the bearing.

● *CIRCULATION OF HEAT-CARRIER LIQUIDS*

Heat-carrier liquids such as, for instance, mixtures of diphenyl oxide and diphenyl, are now being employed on a steadily increasing scale in numerous evaporating, distilling, and chemical reaction processes. These liquids are contained in a closed circuit, and in its heat-receiving portion the liquid is evaporated and the vapour is then conveyed into the heat-consuming apparatus, e.g., the heating coil of an autoclave, when condensation of the vapour releases the required amount of heat. Since the thermosyphonic effect is nearly always not enough to provide a sufficiently high circulating effect, special circulating pumps are usually employed. It has now been proposed to eliminate the need for a pump in systems of this kind, in which the heat-absorbing heat exchanger is located at a lower level than the heat-yielding device producing the desired heating effect. The proposal is to add one or more gases, e.g., hydrogen, helium, or nitrogen, to the heating medium while it is in the liquid state. This gas should be under a pressure corresponding to the desired temperature, and thus it will be partly absorbed by the liquid. Upon evaporation of the liquid, it will be expelled again, thereby enhancing the circulation of the heat-transfer medium. Circulation will be further enhanced by the change in volume of the gaseous phase in dependence upon the temperature. Control of the circulatory speed of the heat-carrier medium can be effected by means of a valve. Storage containers for storing the liquid medium will as a rule also be incorporated into the closed system. Provision can also be made to empty the closed system by using compressed air to force the liquid to flow into the storage container.

● *NEW FIRE-RESISTANT PLASTIC*

The relatively low fire resistance of conventional polyester resins is to some extent responsible for the restricted application of glass-reinforced laminates. Even when containing a high proportion of mineral filler and antimony oxide, most polyester resins fail to meet the general requirements of fire resistance. Moreover, a high proportion of filler destroys the translucency of the material, and this is an important characteristic of these laminates in many applications. It is claimed that these short-comings have now been overcome by the development of a new class of polyester resins, a high degree of fire resistance having been achieved without sacrificing any other desirable properties of the material. The base for this new class of resins is a new stable dibasic acid of heavy molecular weight. This acid reacts smoothly with the usual glycols and with maleic or fumaric acid, to form an integral part of the polyester chain. Unlike many resins, in which fire resistance is achieved by relatively volatile additives, the new resin is claimed to hold a paint film as well as conventional resins, without loss of adhesion or change of colour. It has not been possible so far to stabilise these resins against yellowing on long and continuous exposure to light. It would appear that this feature constitutes the chief drawback as compared with other polyesters. Light ageing does not, however, affect the strength of the material. These resins have conventional curing characteristics and, with the proper catalysts and promoters, can be used with room-temperature cures, high-temperature cures, and short mould cycles. Post-curing is usually not necessary. Should the use of plastic car bodies become general, fire-resistant qualities will most likely be called for, and in this event the new material may prove to be exceedingly suitable.

● *HEATING STEEL BILLETS FOR EXTRUSION*

In the extrusion of steel through forming dies, the heating of the billets is usually effected in conventional furnaces. The resulting heavy scale is abrasive in character and causes rapid wear of the dies, besides reducing the product yield per pound of billet weight. This scale is not fully removed by conventional descaling practice and any portion left on the billets will naturally impair the surface finish of the extruded product, besides damaging the die. In addition, the presence of scale tends to increase the power required for the extrusion process. It is reported that experience has shown that stainless-steel billets heated by conventional methods and equipment, involving long heating periods of several hours, occasionally will not "push" when placed in the press, although heated to the proper temperature. A suggested improvement of the heating procedure is based upon a novel method of supporting and handling billets, while being heated for working large forgings or extrusions. This method, in conjunction with an improved type of heating furnace, is claimed to increase the speed of heating considerably. Briefly, the suggested improvement consists of welding to one end of the billet a steel stud, from which the billet can be suspended. Even at temperatures as high as 2300° F, this weld will be strong enough to support the weight of the billet. By suspending the billet from above, it is then conveyed through a continuous panel type furnace, in which it is rapidly heated to extrusion or forging temperature. After heating, the billet is descaled by immersion in a salt bath and the stud is then sheared off.

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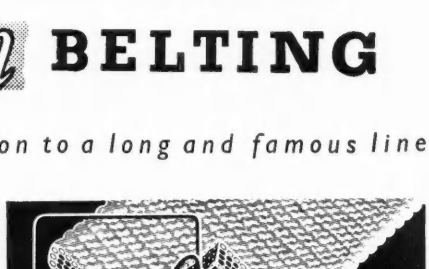

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● NEW CORROSION-RESISTANT COATING

According to a recent report, a new type of anti-corrosion coating may extend the service life and efficiency of heat exchangers, especially cooling and condensing sections. This development should prove particularly important in cases where water, contaminated with salts or acids, or otherwise corrosive, is used. The new anti-corrosion coating is a mixture of finely pulverised aluminium powder in a special plastic vehicle. The metallic particles comprise about 85% by volume of the mixture. The resultant plastic-bonded aluminium coating is claimed to maintain its heat-transfer efficiency while resisting corrosion. The plastic base completely seals the metal particles to make a tightly bonded, flexible, and adherent coating. The cost of applying the coating is said to be less than the cost of a single cleaning operation. If water conditions are severe enough to require periodic cleaning of the cooler or condenser concerned, application of the new coating should result in considerable savings by reducing shut-down time and maintaining full operating efficiency. The manufacturer of the coating material recommends that two or three coats should be applied by brush or spray, so that a coat of not less than seven thousandths of an inch in thickness is obtained. The resultant coat, when properly applied, can be polished, ground, drilled, or bent to a 45-deg angle without chipping peeling, or cracking. Coated sections of coolers and condensers are now under test in contaminated salt water with pH values of between 4 and 5, and have not shown any deterioration after a run of three years. With regard to the range of applicability of this type of coating, it must, of course, be borne in mind that its plastic base precludes its use at elevated temperatures.

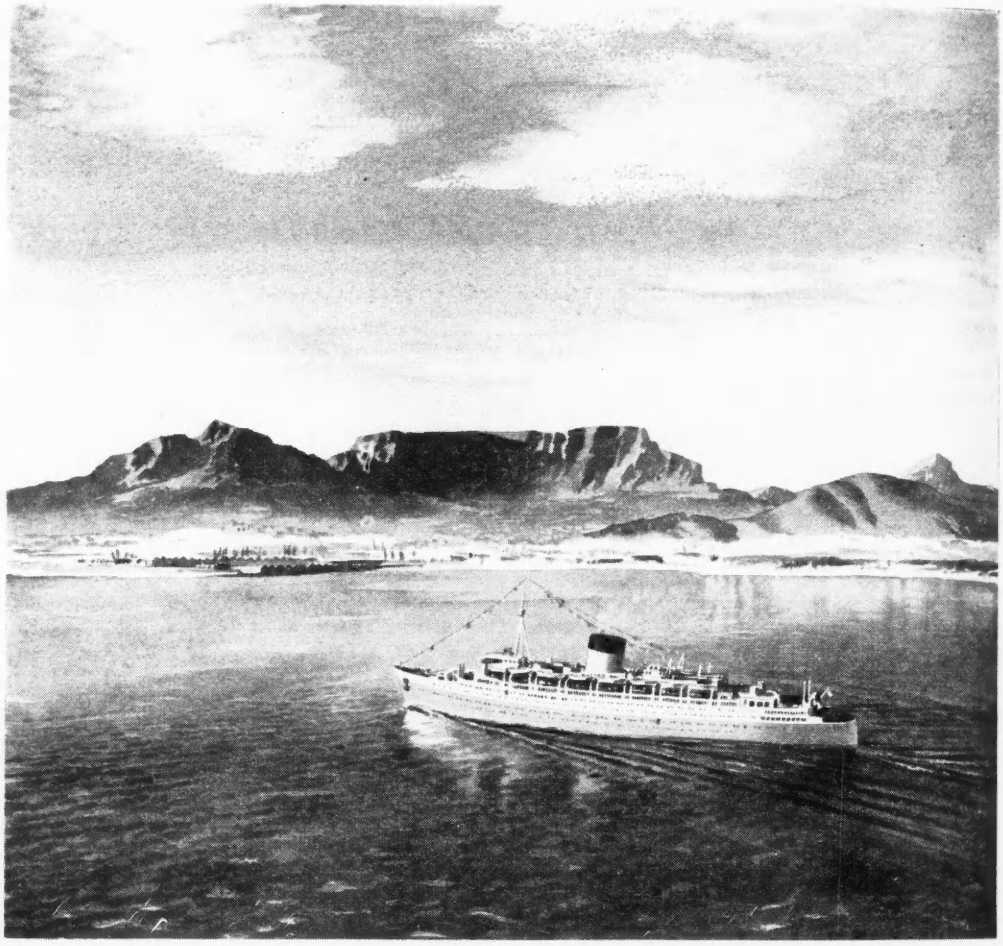
● SPARK TREATMENT OF ENGINE FUEL

A recent invention aims at the improvement of the combustion process in internal combustion engines by electrical means. In describing his method, the inventor explains that his apparatus will serve to decompose or dissociate liquids continuously by subjecting droplets of atomised liquid to the action of electric spark discharges. It is claimed that this method may be successfully applied to all types of internal combustion engines and jet engines, and that its application will result in a very considerable reduction in fuel consumption. Attempts to secure improved combustion conditions by ionising engine fuel mixtures, or engine fuel and combustion air separately by high-frequency electric discharges or by the application of ultraviolet rays have been repeatedly made in the past. The suggestion has also been made to ozonise the combustion air in order to improve the combustion conditions. Referring to proposals to improve combustion conditions by injecting or vaporising water in the fuel mixture, the inventor claims to have observed that, by subjecting this water to spark action, corrosion of engine parts in contact with the fuel mixture is precluded. The sparking effect is to be produced by a combination of stationary and rotary electrodes. To prevent the fuel gas from igniting by the spark action, a special anti-flame device, composed of parallel metal plates charged to an electrical potential below that of the spark voltage, is proposed. A reduction in fuel consumption by as much as 50% is claimed to be obtainable; this claim, as also the utility of the entire method would, however, have to be substantiated by experimental investigations.

● CORROSION-RESISTANT EPOXY RESIN COATINGS

The provision of a reliable corrosion-resistant coating in washing machines presents a most important problem, since it is the determining factor in the service life of the machine. An important step toward the solution of this problem has been taken, it is claimed, by the introduction of newly developed epoxy resins as primers. This new type of primer provides greatly increased resistance to attack from moisture, alkalies, and detergents and possesses better adhesion to the base metal than the alkyd primers hitherto in use. The epoxy resin, which constitutes the basic resin in the primer, is essentially a condensation reaction product of bisphenol and epichloro-hydrin. Effective molecular linkage in these resins is of the stable ether type, rather than the ester linkage typical of alkyd resins, and it is this feature which is responsible for the unique chemical and corrosion characteristics of these resins. Before epoxy primers were adopted, comparative tests of various alkyd and epoxy resin formulations were made. These tests included salt-spray tests of 200 hours duration, humidity tests at 100% relative humidity and 100° F, and immersion tests in salt and detergent solution at 140° F for 380 hours. It is reported that, while epoxyester primers showed superior results over alkyd, the epoxy-urea systems proved to be approximately three times as resistant as the alkyd. When applying the primer, a film thickness of 0·0003 in. is maintained, as against 0·001 in. thickness in the case of alkyd coatings. It is claimed that this thinner coating is less susceptible to variations and requires a minimum of sanding. Because of their excellent physical and chemical properties, these epoxy resins are also being employed in a variety of protective surface coatings, including plant maintenance finishes, can and tank-car linings, and in industries involving chemical, corrosive, and wear hazards.

For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.



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